Materials Engineering in Product Design & Manufacture

Materials & Methods

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Men of Materials . . .

Brenner says . . .
"Plastics limitations should be recognized and lived with . . ."

Dr. Walter Brenner, Chief Chemist, East Coast Aeronautics, Inc. is a specialist in the utilization of plastics materials for low pressure fabrication. A demanding taskmaster of the materials in his field, he has done extensive work in tooling with both metal and plastics, and was an instrumental member of the team that developed vacuum forming. He has contributed to the development of metal-spraying, cathode-sputtering and electroforming techniques for mold making, and has developed heated, matched-plastics dies for plastics molding. Dr. Brenner's constructive criticism of plastics standards represents a growing wave of opinion among plastics engineers and research men.

"There is a widespread reluctance on the part of plastics sales departments to accept many of the basic limitations of current plastics materials. Consider, for a moment, that the common household cooking pot must be able to withstand temperatures far above the range of common organic materials now available.

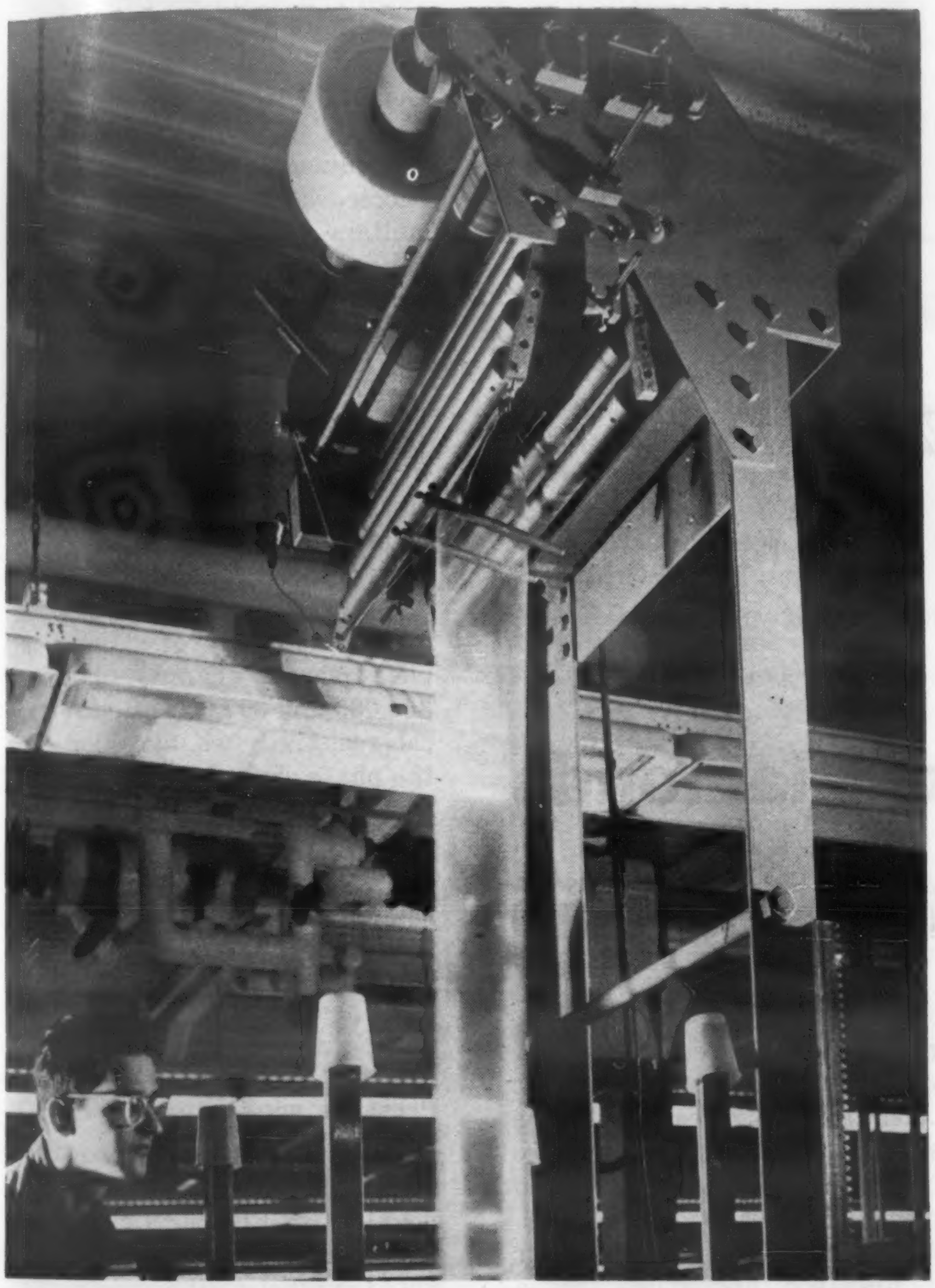
"In order to manufacture and sell good plastics products, we must consider plastics as inherently limited, and we must point out their limitations. The thermal stability of plastics is often overstated. More stringent standards for compounds are necessary. Presently such standards are nonexistent or much too loose. Responsibility for standards development lies within the interests of basic resin manufacturers, who must develop and transmit the data to ensure proper understanding of the limitations and advantages of their materials.

"In the long run, glamorization of plastics materials tends to mislead and injure sales potentials. For example, reinforced plastics are not wonder materials, but are legitimate, useful engineering materials in an early state of development. As a specific case in point, reinforced plastics pipe has already suffered from overpromotion before testing has justified claims. Minimizing current limitations will not lead to the many proper applications that reinforced plastics pipe deserves. In pipe, as in all products, it is necessary to have thorough knowledge of the material, for only once in a thousand tries will a product succeed in an application for which it is untested. No one in any industry can afford to take such a chance on failure.

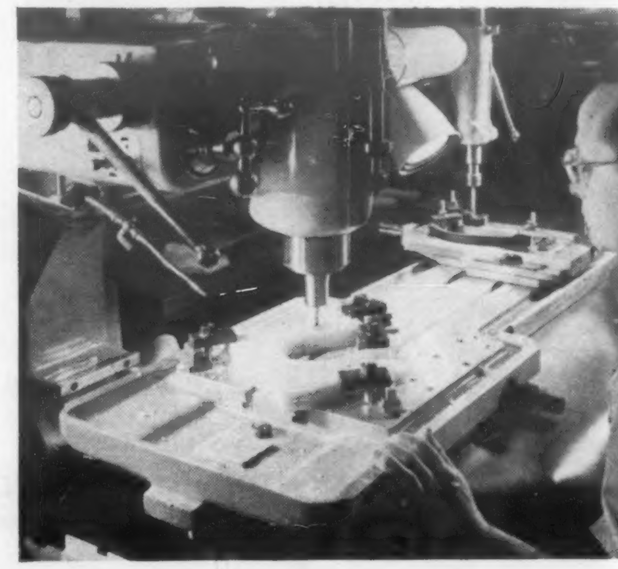
"Plastics for tooling have a tremendous potential. But unless present danger signals are heeded, plastics tools may go down as another failure for plastics. The very word "tool" implies stability. Standards for tooling plastics must be developed so that the toolmaker can depend on his material and not be at the mercy of countless formulations, each of which has different, and perhaps insufficiently tested, properties. The toolmaker must be able to depend on his materials in order to design his molds and dies intelligently.

"Standards and full knowledge of materials can foster progress and profitable sales in the plastics industry more than any other factor. Compare the relative ease of besmirching a woman's reputation with the problem of building it up again. The plastics industry has come of age not unbesmirched, and standards concomitant with the best applications of plastics are long overdue."

For more information, turn to Reader Service Card, Circle No. 366



Polyethylene film *blown in tubular form at sales laboratory installation*



Nylon part *is milled on a pantograph to produce intricate contour of part for testing.*

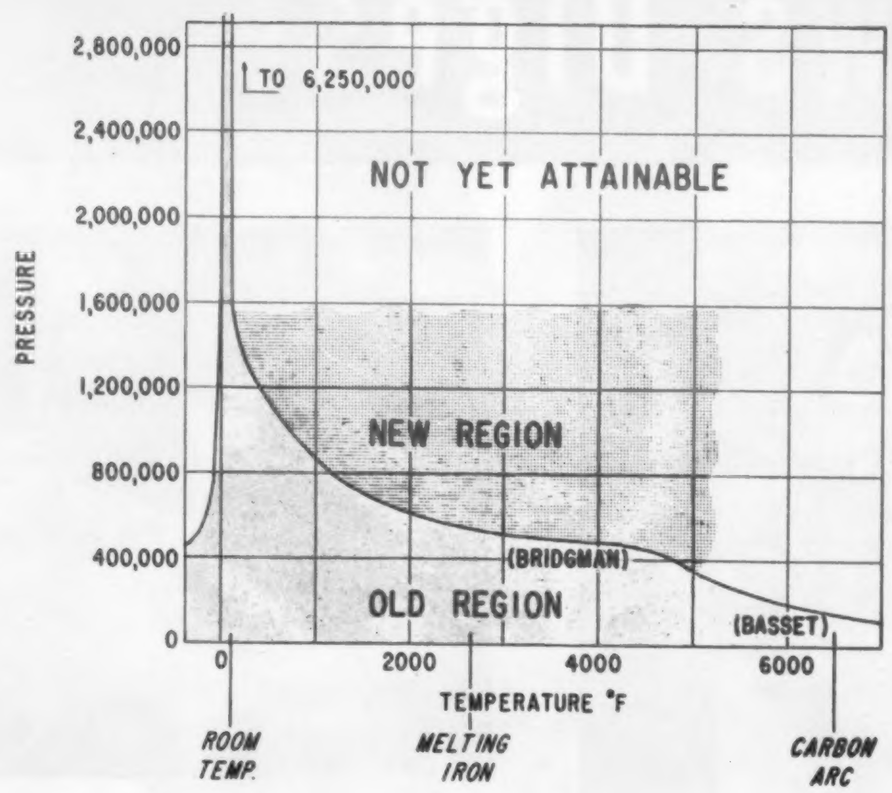
Bank of engine blocks *tests coolants and antifreeze.*

Plastics Lab Opens

To help its customers produce better plastics products, Du Pont's Polychemicals Department has opened a $3,000,000 sales service laboratory at Chestnut Run, near Wilmington, Del. The work in the new laboratory will be divided about evenly between customer assistance and development work on new materials and processes. The lab can duplicate conditions found in general industry and will evaluate new materials under such representative conditions.

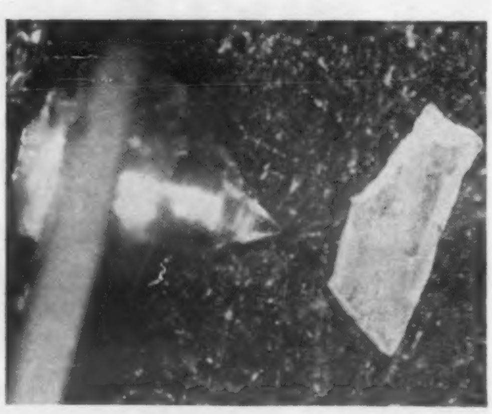
Equipment will be available to process over 100 polychemicals used in industry and agriculture, and includes facilities for molding, extrusion, compounding and forming thermoplastic resins. Auxiliary processing units include radiant heaters, chill rolls, quench tanks, film slitting machines and other allied equipment. A representative variety of types of injection and extrusion molding equipment can test materials with the type of equipment found in molding shops.

The laboratory group has already produced many substantial contributions to plastics technology. Coating paper with polyethylene and the extrusion of acrylic sheet typify its work.



New range of pressures and temperatures makes possible . . .

Graphite to Diamonds in the Lab



Largest diamond *synthesized is about 1/16 in. long (above). It was produced on press below, which is capable of delivering 1.6-million psi.*

The synthesis of diamond from graphite announced last month by General Electric Research Laboratories, revealed that a whole new range of pressures and temperatures had been opened for materials research. Dr. C. G. Suits, G. E.'s Director of Research, announced that a combination of pressure and temperature in the range of 5000 F at 1½ million psi had been maintained for a considerable length of time. Because reactions involving crystallization are time dependent, the ability to hold pressure and temperature at high values for extended periods of time is of basic importance.

Previous limits

Professor Bridgeman, of the Metallurgy Department at Harvard University, is responsible for many of the basic steps leading up to the present development. Bridgeman has succeeded in reaching temperatures of 3500 to 5000 F at pressures in the range of half a million psi for short periods of time. At room temperatures, Bridgeman's multiple stage systems attained pressures of 6,250,000 psi. The General Electric Research Laboratory, applying Bridgeman's techniques with modifications, succeeded in extending the simultaneous pressure-temperature range to the extent shown in the graph.

Standard pressure measurement techniques are useless at the pressures attained in the super-pressure equipment used by Bridgeman and GE. The pressures and temperatures are estimated by interpolating from known phase changes in various crystal structures that take place at specific pressures. For example, bismuth changes phase at 360,000 and 397,000 psi. Electrical resistivity changes indicate the phase change. Other calibration points are obtained from phase transitions in thallium at 640,000 psi, cesium at 785,000 psi, and barium at 1,140,000 psi. General Electric claims to have developed "at least one method" to determine pressure above the phase transformation of barium.

Pressure applications

The simultaneous pressure-temperature range attained by the General Electric Laboratory produced the first fully substantiated synthetic diamond from a mixture of graphite and other materials. Bridgeman has often attempted the graphite-diamond transition, but his equipment could not hold the required temperature at the million-psi plus pressure long enough to attain crystallization.

Although the announcement of the production of diamond by artificial techniques caused a slight flurry in the diamond market, it is doubtful whether industrial diamond could be produced any more cheaply than it can be mined. Annual industrial consumption of 2½ tons of indus-

trial diamonds would be hard to meet due to the difficulties encountered with high temperatures and pressures.

A. J. Nerad, of General Electric's Research Laboratories, was highly optimistic in estimating the value of super-pressure research on other materials. He said, "We look to the super-pressure techniques to yield new forms of matter with properties of scientific value. The structural and phase changes and the chemical reactions that occur only at super-pressures represent a wide field for scientific attention. It should be mentioned that polymerization is also included in the objectives in this field." An example of a super-pressure material not found in nature is Coesite—a high density silica formed at pressures above 500,000 psi. Because it returns to its normal phase at low pressure when heated to 1300 F. it is not found as a natural mineral. By holding the pressure high while cooling the melt, the Coesite form can be maintained by super-pressure techniques.

Ceramic Tools Cut Faster than Carbide

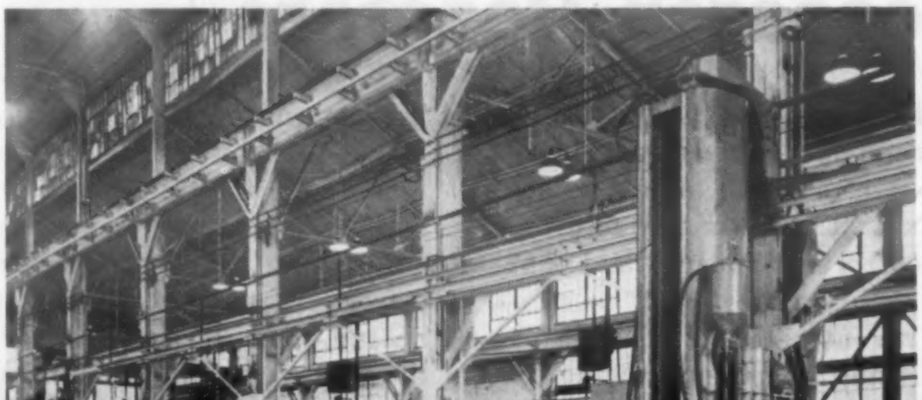
A persistent mechanical engineer at Watertown Arsenal's Rodman Laboratory has succeeded in developing high density ceramic tools for metal cutting. His report states that "cutting tools of alumina base composition . . . were successful in turning (lathe) a variety of metals at considerably higher than normal machining speeds". How much higher is not yet known, since the best the lathe used in the experimental work can turn up is 1200 sfpm.

W. J. Kennedy's work subsequent to his initial report indicates that the high purity alumina compacts can turn metal at three times the speed of carbides, and perhaps higher, at the same depth of cut. The ceramic composition requires a different tool geometry and more rigid machine and tool fixtures. Otherwise, the new tools will cut all the materials that carbides will cut, only faster. The new tool does not pick up heat, has less friction loss, and is more resistant to cratering than carbides. Chips are smooth, and the work piece exhibits about the same surface as a carbide machined specimen.

Ceramic tooling is not new, particularly for nonferrous and nonmetallic machining purposes. However, persistent intelligence reports from Germany during the second World War indicated that ceramics for machining ferrous materials had been developed. Later, the Russians claimed to be using ceramic tools. Research in this country was not pressed, and what little was done was discouraging. Kennedy took on the project over a year ago, and tested fourteen of the most likely ceramics. Professor Norton at MIT suggested that high purity aluminum oxide should be thoroughly investigated for tooling purposes. His advice paid off in the final test.

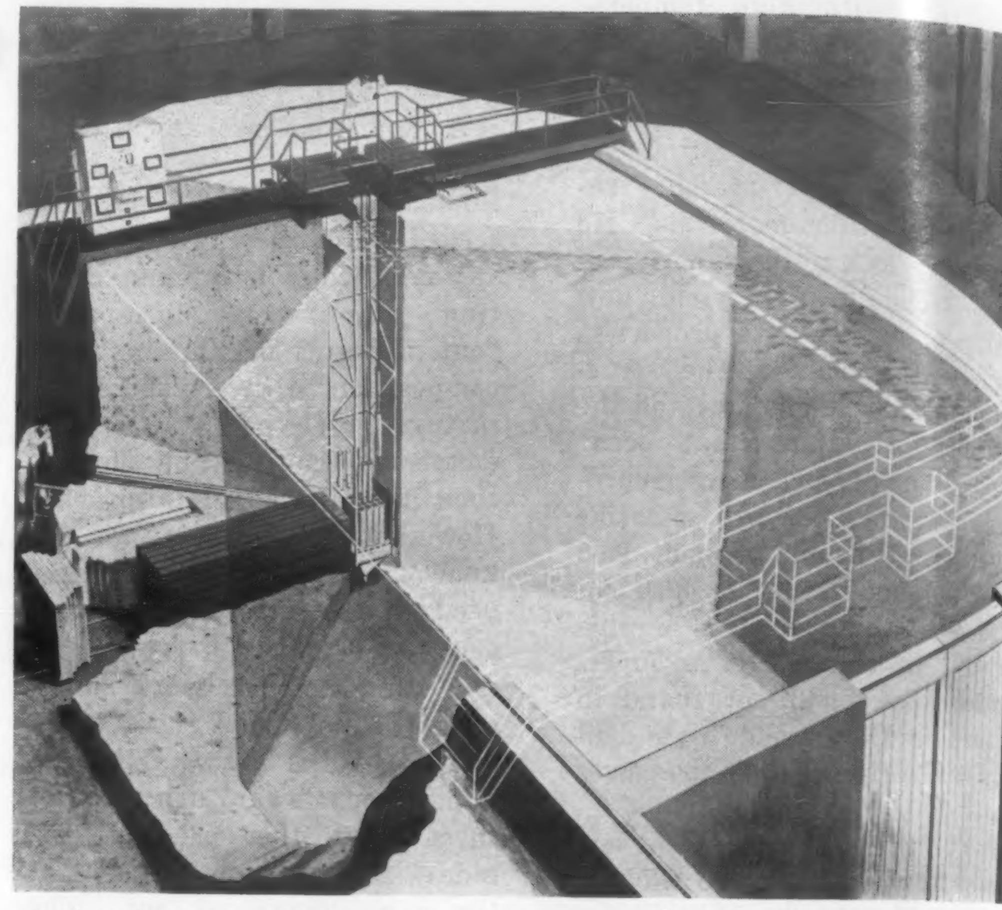
The aluminum oxide tools are made by special techniques of compacting powder and sintering, quite similar to the methods used in powder metallurgy. The tools are more brittle than carbide, but properly supported and protected by mechanical chip breakers, they show excellent wear characteristics. Cost estimates have not been made, but it is believed that the tools will be as expensive as carbides unless large quantities of them are made. Their faster cutting speed is somewhat offset by the particular care that must be exercised in elimination of vibration and securing ultra rigid tool fixtures. However, in case of a shortage of the critical tungsten that is used for carbides, the ceramic tools offer a promising substitute for critical metals.

(More News Digest on page 14)



Largest Welder Claimed to be able to handle larger weldments than any other automatic continuous welder, this machine is now in operation for the Morgan Engineering Co., Alliance, Ohio. Company spokesmen credit the machine with eliminating welding variables, increasing weld strength, and reducing welding costs in girder fabrication over 90%. The welding heads will trace curves and have a longitudinal travel of 110 ft.

News Digest



Swimming-pool reactor *designed by American Machine and Foundry will be built for industrial research.*

Industry Buys Research Reactors

"There is one best way to learn about nuclear reactors," said a consultant to one of industry's largest manufacturers of control equipment, "and that way is to operate one."

With interest in radiation for processing purposes growing by leaps and bounds, and estimated cost of electricity from nuclear fueled plants dropping almost daily, a lot of companies and research organizations are well past the planning stage in setting up industry-owned experimental nuclear piles.

An experimental pile is a costly piece of research equipment, and with accessory equipment usually represents a total investment of well over $1,000,000. What can industry expect to gain from such an installation? And where is industry likely to use the results from this type of facility?

First and foremost, an experimental reactor can offer first-hand experience to the engineers and technicians who will design, build and operate full scale power reactors of the future. Second, and also important, is the use of the nuclear pile as a research tool in its own right. Thirdly, the reactor can produce useful isotopes for industrial tracer work. A reactor is the only source of high density neutrons, and offers a variety of types and densities of other radiations. However, neutrons can be troublesome, particularly in processing operations, as they induce radioactivity in other materials. Processing irradiation will probably be accomplished almost exclusively by particle accelerators such as the Van de Graaff machines built by High Voltage Engineering and the

(Continued on page 206)

Preview

1955 Metal Powder Show 11th Annual MPA Meeting

Members of the Metal Powder Association will reveal the latest developments in powder metallurgy at the society's 11th annual meeting, held at the Bellevue Stratford Hotel in Philadelphia on May 10, 11, and 12. Concurrently at the Metal Powder Show, over 25 leading manufacturers associated with powder metals will exhibit the latest metal powder products and processing equipment.

Technical sessions have been scheduled for the latter two of the three days of the meeting. The exhibition will open on May 10, and attendees will have the full day to contact representatives of the exhibiting companies for help in technical, supply and production problems.

On Wednesday, May 11, the association will hold technical sessions in the morning and afternoon. On Thursday, there will be a morning session and the meeting will close with the annual luncheon. The technical sessions are divided in two groups running simultaneously. The general sessions will cover the field of powder metallurgy from powder production to fabrication techniques. The Electronic Core sessions will deal with the use of powder metals in magnetic applications in radio, television and computer-memory systems.

The Association has made plans for two social occasions during the show. On Wednesday evening, a reception including cocktails and buffet supper will be held at the Bellevue Stratford Hotel. Following the morning technical session on Thursday, the annual luncheon will provide a final opportunity for members to get together.

As in the past, the business sessions and election of new officers of the Metal Powder Association will be held the first day of the show, Tuesday, May 10.

A detailed program and abstracts of papers may be found below.

Program

Tuesday, May 10
Morning

Registration at Bellevue Stratford

Metal Powder Association Business Meetings

Afternoon

Metal Powder Show Exhibit Opens

Wednesday, May 11
9:00 a.m.

Exhibit Opens at Bellevue Stratford Hotel

General Session
9:45 a.m.

Finishing and Plating of Powder Metal Compacts—*Charles Cohn, Director of Research, Colonial Alloys Co.*

Mr. Cohn will discuss the controlling factors in finishing and plating metal powder parts to attain high corrosion resistance and decorative finishes. He will point up pre-cleaning, impregnation with resin, removing excess impregnant, selection of plating bath, calculation of current densities, controlling pH ranges, and the relationship of density to successful plating.

Machining Metal Powder Bronze Bearings—*W. A. Irvine, the Maytag Co.*

Mr. Irvine will show that while some difficulties may be encountered in machining sintered materials, the proper selection of machining speeds, tooling, and cutting fluids for sintered bronze

parts will eliminate machining problems.

Pre Alloyed Steel Powders and Applications—*G. A. Roberts and A. Grobe, Vanadium Alloys Steel Co.*

The use of pre alloyed steel powders for sintered compacts has provided a number of new materials with important characteristics including increased strength, corrosion and temperature resistance. The paper by the engineers from Vanadium Alloys Steel will discuss the properties of these materials and some of their successful uses.

Electronic Core Session 9:45 a.m.

Method of Specifying Iron Powder Cores—*C. E. Cherry, Jr., Metal Powder Association.*

Mr. Cherry will discuss a system to standardize the method of specifying cores.

Some Results of the Evaluation Program for Iron Powder Cores—*E. Both, Squire Signal Laboratories, Signal Corps Engineering Laboratories.*

The Army Signal Corps maintains a constant evaluation testing program. Mr. Both will discuss the results of the program to evaluate core materials.

General Session 2:00 p.m.

Carbide Tooling for Pressing Metal Powders—*T. A. Wilson, National Carbide Die Co.*

The excellent wear resistance of carbide dies makes them highly desirable for long run parts and for compaction of highly abrasive powders. The lack of wear on carbide dies also keeps tolerances accurate over long periods of use and insures a good surface finish.

The Economic Production of Metal Powder Parts in Small Volume—*B. I. Horton, Pitney Bowes, Inc.*

Not the least advantage of producing parts by metal powder

techniques is the low cost of tooling. Mr. Horton will draw on his experience with metal powder part production at Pitney Bowes in analyzing methods to cut costs in producing compacts on a short run schedule.

Some Aspects of Iron-Copper Sintering—*P. Ulf Gummeson, Hoeganaes Sponge Iron Corp.* Copper added to iron powder results in an increase of strength and hardness. Dimensional control, hardness, and strength vary with copper content, sintering time, heating and cooling rates, mesh size, and other factors. With careful control over these factors, it is possible to gain desired hardness and strength at lower sintering temperatures with less copper.

Electronic Core Session 2:45 p.m.

The Various Iron Powders Used in Electronic Cores — *J. A. Roberts and G. O. Altman, Antara Chemicals, a Sales Div. of General Aniline & Film Corp.* A review of different production methods for making iron cores. High frequency characteristics of different iron powders. Major portion of paper deals with practical applications with emphasis on recent developments.

Ferrite Antenna Cores — *C. A. Grimmett, Electronics Div., General Electric Co.* Theory of operation, effect of shape, wire size and core material. Lists characteristics of idealized material and compares with available cores.

Panel Meeting on Threaded Cores

Thursday, May 12 General Session 9:45 a.m.

The Iron Powder Industry in Europe—Present and Future —*S. I. Hulthen, Hoeganaes-Billesholms Aktiebolag*

The striking difference in color shows comparative resistance to oxidation, proves superiority of RESISTOX Metal Powder (left) when exposed same length of time as ordinary powder.

Resistox Process gives Glidden Metal Powders more stability through greater resistance to oxidation!

Glidden Resistox Metal Powders offer you distinct storage and production advantages over ordinary metal powders because they resist oxidation from 5 to 10 times longer!

This exclusive Resistox Process permits storage over long periods of time without fear of oxidation, thus eliminating production and product-quality problems.

Glidden Resistox Metal Powders meet every requirement for uniformity, purity, consistency, strength. There is less material waste and die wear. They permit faster production of precision parts with greatly improved finish, appearance and performance characteristics.

Let us supply you with more complete information on these Glidden products: Resistox Copper and Lead Powders, Cuprous Oxide, Cupric Oxide and Cubond (Copper Brazing Paste). There's no obligation.

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Statistics on current production of powders for various uses will be analyzed by Mr. Hulthen, emphasizing the types of powders used in powder metallurgy. He will also discuss some of the techniques relating to treatment of powders, pressing, tooling and sintering. After a short summary of current powder metal activity in Europe, Mr. Hulthen will attempt to estimate the future trends of powder metal techniques and applications on the continent.

A Powder Producer Looks at Titanium Powder Metallurgy —*J. F. Sachse, Metals Disintegrating Co., Inc.*

The development of titanium as a commercial metal has been assisted by powder metal techniques. Many newer processes yield a powder product and the future may see the production of large sheets without the necessity of melting.

A Fabricator Looks at Titanium Powder Metallury — *H. W. Dodds, The Brush Laboratories Co., A Division of Cleavite Corp.*

A summary of the activities of Brush Laboratories Co. in developing powder metallurgy methods for the fabrication of titanium parts and billets. The advantages and disadvantages of powder metallurgy techniques applied to titanium are discussed. The applications suitable for the two basic fabrication techniques, hot pressing and press forming, are discussed.

Electronic Core Session 9:45 a.m.

Trends in Ferrite Core Design for TV Yokes and Flybacks— *C. E. Torsch, the Rola Co.*

The basic understanding of ferrite magnetism and the emergence of standards have improved set design and performance. Mr. Torsch discusses the role of fer-

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For more information, turn to Reader Service Card, Circle No. 504

rites in the light of these developments.

Application of Ferrites to Memory Systems—*William N. Papian, Staff Member, Lincoln Laboratory, Massachusetts Institute of Technology.*
How millions of ferrite rings can be used in an installation for the storage of binary information. Low cost and high performance stressed.

Application of Ferrites to Deflection Components — *B. V. Vonderschmitt.*
Ferrite horizontal deflection transformers and yokes as applied to color and black and white television. Correlation between bridge measurements and performance.

List of Exhibitors at Metal Powder Show:

Alloy Metal Powders, Inc.
Antara Chemicals
Arnhold Ceremics Inc.
  Subs. of General Ceramics Corp.
Baldwin-Lima-Hamilton Corp.
Chicago Powdered Metal Products Co.
Colonial Alloys Co.
Drever Co.
Electric Furnace Co.
W. J. Fitzpatrick Co.
Charles Hardy, Inc.
Hoeganaes Sponge Iron Corp.
Kux Machine Co.
Lindberg Engineering Co.
MATERIALS & METHODS Magazine
Metal Hydrides, Inc.
New Jersey Zinc Co.
Plastic Metals Div.,
  National Radiator Co.
Precision Metal Molding Magazine
Selas Corp. of America
Sharples Corp.
Stackpole Carbon Co.
F. J. Stokes Machine Co.
Vanadium-Alloy Steel Co.
Whitaker Metals Corp.
Yale & Towne Mfg. Co.,
  Powdered Metal Products Div.

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For more information, Circle No. 420 ›

Recirculating Furnaces. Despatch Oven Co., 12 pp, illus, No. 81. Quick-quenching, bottom-entry furnaces for solution heat treating of aluminum and aluminum alloys. (21)

Phosphate Coating. Detrex Corp., 6 pp, illus. Describes low-cost phosphate coating process that protects iron and steel from corrosion. (22)

Aluminum Finishing. Diversey Corp., 4 pp. Lists company's cleaning and finishing equipment for aluminum. (23)

Butyrate Strippable Plastic. Eastman Chemical Products, Inc., 6 pp, illus. Describes butyrate peelable plastic packaging. Advantages include ease of application and removal, and good corrosion resistance. (24)

Acid-Proof Coatings. Electrochemical Engineering & Mfg. Co., 8 pp, illus, No. G-53. Describes acid and alkali-proof cements as linings and coatings for floors, tanks, etc. (25)

Flame Cutting. Flame Cutting Equipment Co., 16 pp. Clear, concise description of flame cutting process with propane gas. Includes listing of company's available torch tips. (26)

Aluminum Designation System. Peter A. Frasse & Co., Inc. Conversion chart for new designation system with explanation of conversion procedure. (27)

Electrical Insulating Materials. General Electric Co., 8 pp, illus. Lists insulating materials, including varnishes, finishes and mica mat. Properties and applications given. (28)

Protective Atmospheres for Heat Treating. General Electric Co., 12 pp, illus, No. GEA-5907. Describes gas-producing equipment that meets most protective atmosphere needs for preventing deterioration of metals during heat-treating. (29)

Epoxy-Glass. Haveg Corp., 3 pp, No. 6. Description of Haveg 9710, an epoxy-glass having good chemical and thermal resistance. Table indicates performance under various chemical and thermal conditions. (30)

Blind Rivets. Huck Mfg. Co., 4 pp, illus, No. 8-320. Describes permanent blind rivets available in aluminum alloy or cadmium plated steel. (31)

Beryllium Copper Springs. Instrument Specialties Co., Inc., 16 pp, illus, No. 9. Catalog of company's stock of compression springs, flat springs, strip springs, contact strips and contact rings. (32)

Alloy Castings. International Nickel Co., Inc., 48 pp, illus, No. A-141. Discusses heat and corrosion resistant alloy castings. Includes typical compositions, limitations and applications. Charts compare creep strength, corrosion and oxidation resistance of various alloys. (34)

Aluminum Machining. Kaiser Aluminum & Chemical Corp., 4 pp, illus. Outlines advantages of aluminum screw machine stock, including high corrosion resistance, lower machining time and extended tool life. (35)

Cleaning Tanks. Kelite Products, Inc., 2 pp, illus, No. 130-357R01. Hot and cold cleaning tanks for immersion cleaning or processing. (36)

Metal Finishing. Klem Chemicals, Inc., 12 pp, illus. Describes company's facilities for metal finishing. Includes rust removers, strippers, degreasing compounds and electrolytic cleaners. (37)

Welding Aluminum Sheet. Linde Air Products Co., 1 p, No. 54-6R. Instructions for oxyacetylene welding of aluminum sheet. (38)

Induction Heaters. Magnethermic Corp., 12 pp, illus. Describes low frequency brass and copper induction heaters for preheating metals. (39)

Glass and Ceramic Parts. Mansol Ceramics Co., 16 pp, illus. Glass preforms for hermetic seals, adhesives, steatite preform and multiform production facilities. (40)

Welding Electrodes for Cast Iron. Metal & Thermit Corp., 4 pp, illus. Describes electrodes with low melting temperatures for welding cast iron. Recommended applications include welding cylinder blocks and heads, bearing blocks, machine parts and large frames. (42)

Spray Pickling. Metalwash Machinery Corp., 12 pp, illus. Discusses pickling of drawn parts and preparation of steel for porcelain enameling. (43)

Barrel Finishing. Minnesota Mining & Mfg. Co., 12 pp, illus. How barrel finishing works, when to use this process, and what operations barrel finishing performs. A supplementary booklet discusses abrasive chips and compounds for barrel finishing. (44)

Nuts. National Machine Products Co., 12 pp, illus. Describes "Twelve Pointer" nut designed to permit smaller tool clearances than is practical with hexagon nuts. Both plain and self-locking types available. (45)

Insulations. Owens-Corning Fiberglas Corp., 8 pp, illus, No. GL6.C4. Describes fiber insulations having low thermal conductivity and high sound absorption qualities. (46)

Blast Cleaning and Dust Control. Pangborn Corp., No. 227. Describes Rotoblast equipment designed for blast cleaning of castings, forgings and heat treated parts. Emphasizes features of Rotoblast wheel. (47)

Nylon Tubing. Polymer Corp., 6 pp, illus. Describes 1000- and 2500-psi pressure tubing that is corrosion resistant and has wide temperature range. (48)

Tooling Plastics. Ren-ite Plastics, Inc., 4 pp, illus, No. 1001. Describes dimensionally stable tooling plastic for use in laminating or casting without application of heat or pressure. (49)

Chemically Resistant Products. Resistoflex Corp., 6 pp, illus. Folder on chemically resistant industrial hose and plastics. (50)

Aluminum Appliance Parts. Reynolds Metals Co., 20 pp, illus. Discusses use of aluminum parts in appliances such as refrigerators, air conditioners, washers and dryers. (51)

Castings. Rosedale Foundry Corp., 8 pp, illus. Describes company's facilities for producing aluminum, magnesium and bronze sand castings. (52)

Machining Steels. Joseph T. Ryerson & Son, Inc., 4 pp, illus, No. 99-1. Compares machinability of fast-cutting, alloy and stainless steel, including leaded carbon and alloy steels. (53)

Brinell Hardness Tester. Steel City Testing Machines, Inc., 2 pp, illus, No. KE 1154. Three-colored lights on testing machines indicate relative hardness of parts being tested on production basis. (54)

Steel Castings. Steel Founders' Society of America, 4 pp, illus. How parts can be improved by redesigning for steel casting. (55)

Tubing. Superior Tube Co., 8 pp, No. 40. Information on selection and application of 46 principal analyses of tubing. Includes seamless and weld drawn tubing. (56)

Abrasion Resistance Tester. Taber Instrument Corp., 4 pp, illus, No. 5409. Tester evaluates resistance of surfaces to rubbing abrasion. Includes tests of painted, lacquered, electroplated surfaces and plastic coated materials. (57)

Liquid Polymer Compounds. Thiokol Chemical Corp., 4 pp, No. 115. Cold casting liquid polymer compounds having good oil and solvent resistance and low temperature properties. Applications include potting electrical and electronic components. (58)

Tubing. Tube Distributors Co., Inc., 16 pp, illus. Describes plant's facilities for handling seamless and welded tubing requirements. Additional booklets give applications of stainless alloy and carbon steel tubing and information on cold-drawn mechanical tubing. (59)

Aircraft Tubing and Bar Stocks. Tube Distributors Co., Inc., 22 pp. Comparative specifications for alloy stainless and carbon steel aircraft tubing and bar stocks. (60)

Welded Tubing. Van Huffel Tube Corp., 32 pp. Covers sizes, gages and tolerances of square, round, rectangular steel tubing and special cold formed shapes. (61)

Other Available Literature

Irons and Steels • Parts • Forms

Forgings and Castings. Allegheny Ludlum Steel Corp., 28 pp, ill. Smooth hammered forgings, composite die sections, and cast-to-shape steels. Includes a guide to uses and types of cast-to-shape tool steels, with chemical analyses. (62)

Wear Resistant Materials. American Brake Shoe Co., 48 pp, ill. Catalog of representative products; castings, bearing materials, forgings, sintered metals and industrial equipment. (63)

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Manufacturers' Literature

Centrifugally Spun Tubes. American Cast Iron Pipe Co., 4 pp, ill. Stock list of company's centrifugally cast tubes furnished as-cast, rough machined or finish machined. (64)

Low-Alloy Steel. Bethlehem Steel Co., 66 pp, ill, No. 353. Properties and features of Mayari*R steel for use in applications requiring high strength and good wear and corrosion resistance. (65)

Stainless and Nickel Tubing. J. Bishop & Co. Platinum Works, 8 pp, ill. Stainless steel and nickel alloy tubing and small tubular specialties. (66)

Stainless Steel Heads. G. O. Carlson, Inc. Various lists of typical uses and dies available. Price lists included. (67)

Gray Iron and Steel Castings. Campbell, Wyant & Cannon Foundry Co., 24 pp, ill. Describes company's facilities for producing all types of gray iron and steel castings. (68)

Cast Iron. Carondelet Foundry Co., 4 pp, ill. Discusses a variety of modern cast irons controlled and alloyed for industrial requirements. (69)

Enameled Metal Strip. Coated Coils Corp., 4 pp, ill. Describes coiled enameled metal strip supplied in widths up to 30 in. which can be put through operations without damaging the coating. (70)

Steel. Crucible Steel Co. of America, 12 pp, ill., No. T-A1. Catalog lists and describes literature, technical aids and data sheets for production of specialty steel products. (71)

Stainless Steel Tubing and Pipe. Damascus Tube Co., 8 pp, ill. Profusely illustrates the manufacturing process of stainless steel tubing and pipe offered by Damascus. (72)

Steel Fabrication. Delaware Steel Fabricating Corp., 4 pp, ill. Company facilities for steel fabrication and list of representative products. (73)

Custom Steel Parts. H. Disston & Sons, Inc., 16 pp, ill. Describes custom steel parts, how they are made and how to use and order them. (74)

Forged Metal Quality. Drop Forging Assn., 6 pp, ill. Detail of several hot working processes emphasizing improvements achieved in metal structure using these processes. (75)

Corrosion Resistant Castings. The Duraloy Co., 16 pp, ill, No. 3150-G. Describes facilities for manufacture of chromium-iron and chromium-nickel castings. Gives detailed properties of alloys and their uses. (76)

Flexible Metal Hose. Flexonics Corp., 16 pp, ill. Catalog of expansion joints and flexible metal hose. (77)

Metal Stamping. Fred Goat Co., Inc., 18 pp, illus. Specification and application data for varieties of tube shields, clips, caps and rings. (78)

Stainless Steel Castings. Kolcast Industries, Inc., 4 pp, ill. Large stainless steel precision castings made by the frozen mercury process. (79)

Ductile Iron Castings. Lynchburg Foundry Co., 12 pp, ill. Describes ductile cast iron with detailed description of its properties and suggested applications. (80)

Stainless Steel Castings. The Ohio Steel Foundry Co., 4 pp, ill, No. 651-C. Compositions of Fabrite stainless steels for casting and illustrations of numerous corrosion resistant castings. (81)

Forgings. Pittsburgh Forgings Co., 8 pp, ill, No. 5201. Describes and illustrates the facilities of this company for producing drop, press and upset forgings. (82)

Powder Metal Parts. Powdered Metal Products Corp. of America. Booklet shows advantages of powder metallurgy in manufacture of such parts as gears, sprockets and valves. (83)

Investment Castings. Precision Metalsmiths, Inc. Entitled "Pour Yourself an Assembly," this booklet describes this company's facilities for casting in 160 different ferrous and nonferrous alloys. (84)

Metal Containers. Pressed Steel Tank Co., 16 pp, ill. Tells how many industries have been helped in quality production at low cost by use of Hackney Metal containers and deep drawn component parts. (41)

Steel Tubing. Rochester Products Div., General Motors, 12 pp, ill, No. 271. Features typical applications of GM tubing made in both single and double walls of steel. (85)

Steel Wire Rope. John A. Roebling's Sons Co., folder, ill. Describes the manufacture of steel wire rope from the manufacture of the steel through to the finished rope. (241)

Precision Investment Casting. Alexander Saunders & Co., 12 pp, ill. Advantages in comparison with conventional methods of producing precision investment castings, technique, and equipment and supplies needed. (86)

Strip Steel, Etc. Superior Steel Corp., 12 pp, ill. Detailed data on the proper selection of Superior strip steels, stainless steels, Su-Veneer Clad Metals, alloy and spring steels, etc. (87)

Steel Forgings. Titusville Forge Div., Struther Wells Corp., 8 pp, ill. Describes facilities for precision forging of parts regardless of size, metal or alloy. Shows numerous parts produced. (88)

Cold Rolled Steel. Thomas Strip Div., Pittsburgh Steel Co., 50 pp. Complete table on pound for lineal foot in weight for cold rolled strip steel in widths of ¼ to 24 in., thicknesses from 0.001 to 0.2757. (89)

Small Precision Metal Parts. Torrington Co., 4 pp, ill. Illustrates the various small precision metal parts custom-made by the Specialties Div. of Torrington. (90)

Tool Steels. Universal-Cyclops Steel Corp., 8 pp, ill. Description, properties and applications of seven tool steels, designed for specific uses in machining and die work for the fastener industry. (91)

To obtain literature appearing on these pages, please refer to easy-to-use reply card on pages 65 and 66

Steel Strip. Weirton Steel Co., 20 pp, ill. Characteristics of electrolytic zinc-coated sheets and strip, high-tensile steel and high carbon strip cold-rolled spring steel being manufactured by the company. (92)

Nonferrous Materials • Parts • Forms

Precision Die Castings. Advance Tool and Die Casting Co., 3 pp, ill. Gives physical composition and average properties of zinc and aluminum alloys and illustrates some of the facilities for producing die castings. (242)

Precision Investment Castings. Arwood Precision Casting Corp., 16 pp, ill. Informative article on precision investment castings. Includes table of ferrous and nonferrous alloys recommended as most adaptable for this process. (93)

Precision Castings. Atlantic Castings and Engineering Corp., 12 pp, ill. "High-Quality Precision Castings for Industry" illustrates Atlantalloy casting process, gives specifications and describes all specified metals, their characteristics and uses. (94)

Vacuum Die Casting. Aurora Metal Co., 8 pp, ill. Describes process for aluminum bronze and silicon bronze. Applications, physical and chemical specifications. (95)

Beryllium-Copper Springs. Beryllium Corp., 6 pp. Lists advantages of using beryllium-copper as a spring material, and gives physical and mechanical properties. (96)

Bronze Bearings. Bunting Brass & Bronze Co., 64 pp, ill, No. 152. Pocket-size booklet contains complete list of industrial standard stock bearings, electric motor bearings and precision bronze bars. (97)

Machining Titanium. Cincinnati Milling Machine Co., 16 pp, ill, No. M-1866. Discusses machining characteristics with emphasis on chip formation. (98)

Powder Metallurgy Parts. Detroit Sintered Metals Corp., 4 pp, ill. Lists metal specifications for sleeve bearings, bushings and intricate shapes. (99)

Zinc Die Castings. Dollin Corp., 4 pp, ill. Describes high-speed automatic production of a variety of simple or intricate small zinc die castings. (100)

Titanium Metal. E. I. du Pont de Nemours & Co., Inc., Pigments Dept., 12 pp, ill. Specifications for titanium metal, strengths of structural materials compared to titanium at ambient and elevated temperatures, mechanical properties of commercially pure titanium and its alloys, fabrication data for titanium metals and alloys, table of corrosion resistance of commercially pure titanium. (101)

Elgiloy. Elgin National Watch Co., Abrasives Div., 2 pp. Corrosion resistant data and other characteristics of corrosion and fatigue resistant alloys. (102)

Investment Castings. Engineered Precision Casting Co., 8 pp, ill. Complete data on EpCo precision investment castings of stainless steel, alloy tool steel, beryllium-copper and most metals that can be melted. (103)

Manufacturers' Literature

Magnesium Castings. General Magnesium Foundries, Inc., 4 pp, ill. Profusely illustrates the facilities of this company for producing magnesium castings. (104)

Metal Stampings. Geometric Stamping Co., 4 pp, ill. Suggestions for cost savings through conversion from castings to stampings. (106)

Copper and Brass Tubing. H & H Tube & Mfg. Co. Describes a complete line of seamless braze and lock seam copper and brass tubing. (107)

Bright Nickel. Harshaw Chemical Co., 4 pp, ill. Process combines brightness and good ductility for applications where little or no basis-metal finishing is done prior to plating. (108)

Aluminum Extrusions. Harvey Aluminum Div., Harvey Machine Co., 8 pp, ill. Properties, characteristics and application of a variety of aluminum extrusions produced by this company. (109)

Investment Castings. Hitchiner Mfg. Co., 12 pp, ill. Description of precision investment castings and its advantages and limitations. (110)

Die Castings. The Hoover Co., 12 pp, ill, No. 853. Shows this company's facilities for producing zinc and aluminum die castings. Includes design helps, describes applications. (111)

Centrifugal Castings. Janney Cylinder Co., 25 pp, ill. Describes wide variety of finished machined centrifugal castings available. Lists alloys and their properties and types of products. (112)

Metal Working Facilities. Jarecki Machine & Tool Co., 24 pp, ill. Facilities for producing tools, dies, production stamping. (113)

Precision Die Castings. The Jelrus Co., Inc., 4 pp, ill. Illustrates cost savings in parts production through use of nonferrous precision die casting methods. (114)

Cemented Carbide. Kennametal Inc., 73 pp, ill, No. 54. Specifications and net prices of Kennametal carbide tools; expanded line of profiling tools. (115)

Alloy Metals. Littleford Bros.. Inc., 4 pp, ill. Facilities for fabricating large assemblies and small parts from various metal alloys. (116)

Titanium. Mallory-Sharon Titanium Corp., 4 pp, ill. Properties of commercially pure unalloyed titanium produced by double melting. Recommended techniques for fabricating and forming titanium sheet. (117)

Zinc and Zinc Alloys. Matthiessen & Hegeler Zinc Co., 6 pp. Physical properties and discussion of various processes that lend themselves particularly to zinc and zinc alloys. (118)

Aluminum and Zinc Castings. Monarch Aluminum Mfg. Co. File pages on this company's developments in aluminum and zinc castings. Each folder distributed kept up-to-date. (119)

Zinc and Aluminum Die Casting. National Die Casting Co., 8 pp, ill. Description of company's die making, die casting and machining facilities. Tables of compositions and specific gravity. (120)

Brass Metal Powder Parts. New Jersey Zinc Co., 4 pp, ill, No. 9. Powder-metal application case histories for lock cylinders, radio transmitter parts and instrument clamps. (121)

Copper Tubing. Penn Brass & Copper Co., 6 pp, ill. Features of this company's seamless copper tubing. Includes tables of safe internal working pressures of various tubing sizes. (243)

Aluminum Castings. The Permold Co., ill. Shows how continuous scientific control of Permold aluminum casting quality, to specifications, saves time and money. (122)

Spun Shapes. Phoenix Products Co., Metal Spinning Div., 4 pp, ill. Describes Phoenixspun methods for spinning spherical and extra deep-drawn contours. (123)

Bushings. Randall Graphite Bearings, Inc., 12 pp, ill, No. 100. Complete price list of bronze bushings and specially grooved bushings; specifications of bored and solid bronze bars. (124)

Machining of Titanium. Rem-Cru Titanium, Inc., 8 pp, ill, Vol. 1, No. 1. Discusses titanium machining practices and procedures recommended by customers having titanium application experience. (125)

Centrifugal Castings. Sandusky Foundry & Machine Co., 6 pp, ill. Specification chart for ferrous and nonferrous alloys for centrifugal castings. (126)

Vacuum Metallizing. F. J. Stokes Machine Co., 22 pp, ill. Describes process and lists applications. Gives specifications for Stokes vacuum metallizing equipment. (127)

Light Metal Castings. Thompson Products, Inc., 8 pp, ill. Describes a complete line of precision die castings for various industrial uses. (128)

Brass Wire for Cold Heading. Titan Metal Manufacturing Co., 4 pp, ill. Outlines tempers recommended for cold-headed parts. Grain sizes, weights and tolerances of Titan brass given. (129)

Aluminum Wire. U. S. Rubber Co., 30 pp, tables. A handbook describing the uses and properties of aluminum for power and lighting wire. (130)

Nonferrous Castings. Wellman Bronze & Aluminum Co., 16 pp. ill, No. 53. Includes facilities of this company for producing a variety of nonferrous castings and wood or metal patterns. (131)

Screw Machine Products. Westfield Metal Products Co., 4 pp, ill. Describes facilities for the production of a variety of machines, nuts and screw machine products. (132)

Spun Tubing. Wolverine Tube Div., 28 pp, ill. Advantages and numerous applications of this firm's nonferrous Spun End Tube Process. (133)

Light Metal Forgings. Wyman-Gordon Products Corp., 4 pp, ill. Announces the availability of large-size light alloy forgings, particularly those of magnesium and 75-S aluminum. (134)

Nonmetallic Materials • Parts • Forms

Plastic Pipe. American Agile Corp., 12 pp. Charts give physical and mechanical properties of polyethylene and polyvinyl chloride pipe and tubing and their chemical resistance to various reagents. (135)

Thermosetting Plastics. American Cyanamid Co. Thirty success stories show outstanding sales advantages of using Cyanamid plastics, which are hard-wearing, hard-surfaced and hard-to-break. (136)

Gasket Materials. Armstrong Cork Co., 24 pp, ill. Complete data on various cork and rubber gasket materials made to meet government specifications. (137)

Thermoplastics. Bassons Industries Corp., 12 pp, ill. Complete data on reinforced and formed plastics. Illustrates processing facilities. (138)

Thermosetting Resin. Celanese Corp. of America, Folder M-1, 6 pp. Physical properties and process characteristics of the MR series liquid low-pressure thermosetting resins for laminating, casting, coating, impregnating and molding. Folder M-2, 6 pp. Describes the Marco method for producing laminates with low-cost mating molds. (139)

Plastisol. Chemical Products Corp., 8 pp, ill. Chem-O-Sol plastisol formulation for industrial and consumer products. Instructions for use and several case histories of coated products. (140)

Compounded Elastomers. Chicago Rawhide Mfg. Co., 32 pp, ill. Characteristics, properties and engineering applications of Sirvene compounded elastomers. (141)

Extruded Plastic. Conneaut Rubber and Plastics Co., 4 pp, ill, No. CR-53. Die making and production facilities of rubber and plastic extrusions. (142)

Coated Fabrics. Connecticut Hard Rubber Co. Uses, chemical, electrical and mechanical properties, and availability of heat resistant silicone rubber coated glass fabrics. (143)

High Strength Plastics. Continental-Diamond Fibre Co., No. GF-50. Properties, descriptions and applications of five of this company's high strength plastics. (144)

Molded and Extruded Rubber. Continental Rubber Works, 8 pp, No. 100. Gives dimensions of molded and extruded rubber with cross sectional illustrations. Also condensed SAE and ASTM specification chart. (145)

Plastic. Crane Packing Co., 12 pp, ill, No. T-103. Complete data on Chemlon packings and gaskets fabricated from the new tetrafluoroethylene resin, Teflon. (146)

Plastics. The Dow Chemical Co., 20 pp, ill. Products, applications and technical services outlined in this brochure on Dow's line of plastics which includes Styron, Ethocel, Saran and Vinyls. Includes charts of properties, case histories of applications and description of engineering services offered by the company. (147)

Plastics Fabrication. E. I. du Pont de Nemours & Co., Inc., 8 pp, ill, No. 51. Property and application data on nylon, polyethylene, tetrafluoroethylene and acrylic resins. (148)

Industrial Textile Fibers. E. I. du Pont de Nemours & Co., Inc., Textile Fibers Dept., 20 pp. Consideration of synthetic fibers as industrial materials. Includes rayon. acetate, nylon, orlon, dacron, teflon fibers. (149)

Polyester Film. E. I. du Pont de Nemours & Co., Inc., 16 pp, Nos. TR-1,

Manufacturers' Literature

TR-2. The physical, chemical and electrical properties of Mylar film. Second pamphlet describes adhesive developed for bonding Mylar to other materials. (150)

Dry Coloring Polyester Resins. Ferro Corp., 2 pp. Explains types of colors manufactured by Ferro that can be used in the dry state. (152)

Thermoplastic Resins. Firestone Plastics Co., Div. of Firestone Tire & Rubber Co., 20 pp, ill. Properties and use of Exon vinyl resins. Describes technical service facilities available. (153)

Glass-Silicone Laminate. The Formica Co., 4 pp, ill. Glass-Silicone laminate for use in sealed, dry-type transformers. (154)

Plastic Products. General American Transportation Corp., Plastics Div., 10 pp, ill. Brochure shows plant facilities for production from blueprint through assembly and packing. Also lists wide variety of this company's molded plastics. (155)

Polyethylene Tubing. Gering Products, Inc., 4 pp, ill. Describes Ger-Tube, a polyethylene tubing which is nontoxic and has good chemical resistance. (156)

Rubber-to-Metal Adhesive. General Tire & Rubber Co., Chemical Div., 8 pp, ill, No. 4016. Complete data on Kalabond rubber-to-metal adhesive for non-corrosive solvent-resistant bonding. (157)

Metallized Plastic Sheeting. Gomar Mfg. Co., Inc., 3 pp. Describes vacuum forming process and applications for metallized thermoplastic sheeting. (158)

Impact Resistant Resin. B. F. Goodrich Chemical Co., 8 pp, ill. Describes resins 404HI and 103EP. 404HI is a new resin with outstanding impact strength. 103EP has high chemical resistance. (159)

Polyvinyl Chloride Resin. Goodyear Tire & Rubber Co. Describes resin developed for extruded wire insulation materials. Properties and composition given. (160)

Packing. Greene, Tweed & Co., 16 pp, ill, No. PC-101. Specifications, descriptions and applications of Palmetto packing, gaskets, asbestos rope and wick. (161)

Adhesives. Hercules Powder Co., 32 pp. The use of Vinsol resin as a low-cost component of adhesives. Product applications divided into rubber-base adhesives, vinyl resin adhesives, and adhesives based on styrene, phenol, urea-starch, cellulose, and polymerized oil. (162)

Polyester Resins. Hooker Electrochemical Co. Folder of data sheets describing fire-resistant and polyester resins. (163)

Plastisols. Houghton Laboratories, Inc., 4 pp, ill. Includes typical applications and specifications of the Hysol 3000 series of plastisols—dispersions of high molecular weight polyvinyl chloride resins in selected liquids called plasticizers. (164)

Rigid Polyvinyl Chlorides. Kaykor Industries, Inc., Div. of Kaye-Tex Mfg. Corp., 6 pp. Chemical and physical properties of Vyflex rigid polyvinyl chloride plates and sheets. (165)

Molded Plywood. Keller Products, Inc., 12 pp, ill. Booklet describes standard and constantly used die shapes for molding plywood as an aid to designers of molded plywood shapes. (166)

Compression Molded Plastics. Kuhn & Jacobs Molding & Tool Co., 10 pp, ill, No. E-604. Illustrates the facilities of this company for producing compression molded plastics. Includes specifications. (167)

Glass. Libbey-Owens-Ford Glass Co., 8 pp, ill. Glass in product and engineering design. (168)

Vibration Control Materials. Lord Manufacturing Co., 12 pp, ill. Stock list of vibration-control shock mounts and couplings. (169)

Reinforced Wood. Met-L-Wood Corp., 15 pp, ill, No. 521. Describes combined wood and metal sheets, providing light weight and high strength. (170)

Insulating Material. Mica Insulator Co. Catalog of standard electrical insulating materials. (171)

Corrosion Proof Tubing. Samuel Moore & Co., 4 pp, ill, No. L-6506. Shows ways to overcome corrosion and high tubing installation through the use of Dekoron instrument tubing. (172)

Molded Rubber. Parker Rubber Products Div., Parker Appliance Co., 4 pp, ill, No. 5201A1. Custom molding facilities for rubber parts. (173)

Industrial Tape. Permacel Tape Corp., 5 pp. Tape for electrical use, bonding and sound damping. (174)

Precision Molded Thermoplastics. Plastic Molded Parts, Inc., 6 pp. Facilities available for Zytel and other thermoplastic precision moldings. (175)

Corrosion Resistant Gasketing. Products Research Co., 5 pp, ill. Features, advantages and specifications of Chromelock corrosion resistant gasketing material. (176)

Carbon Graphite. Pure Carbon Co., Inc., 32 pp, ill, No. 52. Technical data on description, properties, applications and specifications of Purebon carbon graphite. (177)

Plastics. Regal Plastic Co., 4 pp, ill. Facilities for the fabrication of plastic products. (178)

Steatite Ceramic. Star Porcelain Co., 1 p, No. 600. Standard ways of insulating washers and bushing of steatite for high temperature insulation applications. (179)

Rubber Parts. Stillman Rubber Co., 24 pp, ill. Facilities and products of custom molding company. (180)

Molded and Extruded Rubber Parts. Tyer Rubber Co., 8 pp, ill, No. 1P52. Detailed information on various types of molded and extruded parts of natural and synthetic rubber. (181)

Refractory Binders. Union Carbide & Carbon Corp., 20 pp, ill, No. F-8265. How to use ethyl silicate as a refractory mold binder in precision investment casting. (182)

Carbon Graphite. U. S. Graphite Co., 4 pp, ill. Describes Graphitar, carbon-graphite nonmetallic that is chemically resistant, self-lubricating, hard, light and won't warp. (183)

Plastic Laminates. Winner Mfg. Co., Inc., 12 pp, ill. Features the varied facilities of this company and gives typical applications of its many plastic low-pressure laminate products. (184)

Finishes • Cleaning and Finishing

Sodium Nitrite. Allied Chemical & Dye Corp., Solvay Process Div., No. SP-23A. Describes uses of sodium nitrite for protecting metal surfaces against rust or corrosion. (185)

Cleaning and Finishing Media. Almco Div., Queen Stove Works, Inc., 10 pp, ill. Features and applications of Supersheen Abrasive Chips and Compounds for barrel finishing and cleaning. Also data on finishing machines. (186)

Metal Coatings. American Chemical Paint Co. Illustrated folder, check list and reference guide to chemicals and processes for metal preservation. (187)

Coated Abrasive. Carborundum Co., Coated Products Div., 8 pp, ill, No. 2. Characteristics and applications of Resin Industrial Cloth, a new coated abrasive product for dry-belt grinding. (188)

Air Dry Lubricant. Electrofilm Corp., 4 pp, ill. Complete data on Lubro-bond, a dry film lubricating compound specifically designed to meet the anti-friction requirements of industry. Prices included. (189)

Spray Painting. Finish Engineering Co., Inc.. 14 pp, ill. Equipment for masking and spray painting small parts in production volume. (190)

Plastic Coatings. R. M. Hollingshead Corp., 16 pp, ill. Manual on "cocoon" sprayable vinyl plastic coating with instructions on spraying methods. (191)

Silicone-Base Finish. Midland Industrial Finishes Co. Brochure describes silicone-base finish, said to resist heat of 500 F without discoloration. (192)

Coating for Zinc Surfaces. Neilson Chemical Co., No. 48-49. Describes Galvaprep, coating providing good adhesion of paint on galvanized iron, other zinc-coated surfaces. (193)

Wrinkle Finishes. New Wrinkle, Inc., ill. Folder shows typical products utilizing Wrinkle finishes. (194)

Metal Cleaners. Northwest Chemical Co., 4 pp. Chart for selecting proper cleaners for use prior to plating or organic finishing. (195)

Steel Coating. Oakite Products, Inc., 12 pp, ill. Explanations of problems involved in securing paint adhesion to steel and protecting painted surfaces from electrochemical corrosion. Action of Oakite Chryscoat HC in coating steel surfaces. (196)

Wear Resistant Coating. Parker Rust Proof Co., 12 pp, ill, No. A1062. Advantages of using Parco Lubrite, method of applications, typical coating equipment and typical parts that are benefited. (197)

Fluorine Resin Coatings. Permolite, Inc., two 4-page bulletins. Fluor-O-Alloy coatings based in trifluorochloroethylene polymer. Includes corrosion resistance data and application data. (198)

Manufacturers' Literature

Paint Spray. Ransburg Electrocoating Corp., 16 pp, ill. Description of electrostatic spray paint process for automatic industrial applications. (199)

Emulsion Cleaners. Turco Products, Inc., 10 pp, ill, 106 Series Technical Sheets. Charts, uses, methods of applications, safety precautions, etc., for seven types of emulsion cleaners. (200)

Chemical Porcelain. U. S. Stoneware Co., 8 pp, ill, No. CP-50. Describes line of chemical porcelain pipe, fittings, valves, expansion joints, packing, etc. (201)

Finishing Forgings. J. H. Williams & Co., 20 pp, ill. Describes company's facilities for all phases of forging, including cleaning and finishing. (202)

Heat Treating • Heating

Induction Heating Furnaces. Ajax Electrothermic Corp., 12 pp, ill, No. 13-A. Includes advantages and applications of a complete line of Ajax-Northrup high frequency furnaces for forging, upsetting, pinning, annealing, hardening, etc. (203)

Continuous Quenching Tanks. American Gas Furnace Co., 4 pp, ill, No. 820. Specifications of complete line of continuous automatic quenching tanks. Shows several factory installations. (204)

Roller Hearth Furnaces. Drever Co., 8 pp, ill, No. B-90. Profusely illustrates a variety of oil, gas or electrically heated, direct fired or radiant tube roller-hearth furnaces. Includes specifications. (205)

Conveyor Furnaces. Harper Electric Furnace Corp., 4 pp, ill, No. 454. Decribes mesh belt conveyor furnaces. Gives specifications and dimensions. (206)

Metal Baskets. Hoffman Co., 7 pp, ill. Describes this company's metal baskets, for use in such processes as heat treating, cleaning, dipping and plating. Price list included. (207)

Heat Treating. Misco Fabricators, Inc., 4 pp, ill. Describes company's carburizing boxes, fabricated trays, heat treating fixtures, heat treating baskets, retorts, hoods and mufflers. (208)

High Frequency Heating. New Rochelle Tool Corp., 16 pp, ill. Describes the principles of induction and dielectric heating. Includes typical specific applications of high frequency heating in welding, brazing and heat treating. (209)

Quenching Oils. Sun Oil Co., 8 pp, ill, No. A-2658. Complete data on Sun quenching oils, which can handle 95% of all quenching jobs in industrial heat treating. (210)

Electric Radiant Panels. Edwin L. Wiegand Co., 4 pp, ill, No. L-1093. Detailed specifications of the new Chromalox electric far infrared radiant panels for heavy-duty industrial heating, drying and curing operations. (211)

Welding • Joining

Brazing Alloys. The American Platinum Works, 46 pp, ill. Handy-sized manual gives detailed description of the brazing process, the alloys used, design of joints and other considerations for successful joining. (212)

Welding Electrodes. Ampco Metal, Inc., 4 pp, ill, No. W-25. Characteristics and properties of bronze welding electrodes, with list of specific applications for various grades. (213)

Bolts, Nuts and Screws. Buffalo Bolt Co., Div. of Buffalo Eclipse Corp., 150 pp, ill, No. 51. Comprehensive guide for purchasing bolts, nuts and screws, includes blueprints, specifications and prices. (214)

Fastening Pins. C. E. M. Co., 4 pp, ill. Advantages and examples of how Spirol Pins overcome the inherent shortcomings of fastening pins due to their spiral cross-section. (215)

Weldment Assemblies. Continental Foundry and Machine Tool Co., 6 pp, ill. Advantages of large welded assemblies, typical applications, and production facilities available. (216)

Explosive Rivets. E. I. du Pont de Nemours & Co. (Inc.), Explosive Dept., 39 pp, ill, No. A-2785. Gives sizes, installation and variety of uses of du Pont's explosive rivets. (217)

Paste Alloy Solders. Fusion Engineering, 4 pp, ill. Flux-containing electrical, electronic and mechanical bond paste solders and brazing alloys. (218)

Keying and Pinning. John Gillen Co., Inc., 4 pp, ill. Machined keys and pins for production assembly. (219)

Arc Welding Electrodes. Metal & Thermit Corp., 30 pp, ill. Application and procedure data on Murex mild steel and low alloy arc welding electrodes. Contains formulas for estimating welding costs and heat treating procedures, and hardness conversion tables. (220)

Welding Nuts. Midland Steel Products, Inc., 4 pp. Self-locating nuts for faster assembly where nut is welded to plate. (221)

Fasteners. Milford Rivet & Machine Co., 12 pp, ill, No. MM52. Detailed information on an integrated service of fastener research, design, engineering and production collaboration. (222)

Lock Screw Fasteners. Russell, Burdsall & Ward Bolt & Nut Co., 3 pp, ill. Features, advantages and dimensions of this company's spin-lock screws. (223)

Brazing Alloys. United Wire & Supply Co., 3 pp, ill. Wire brazing aluminum for low temperature brazing of various metals and alloys. (224)

Forming • Casting • Molding Machining

Compacting Press. Baldwin-Lima-Hamilton Corp., 4 pp, ill, No. 3104. Describes the Model "L" 50-ton powdered metal compacting press, and lists its design specifications. (225)

Shell Molding. Durez Plastics and Chemicals, Inc., 26 pp. Durez guide to shell molding. Tells methods, material, equipment used in shell molding. (226)

Springtites and Sems. Eaton Mfg. Co., 4 pp, ill, folder C-49a. Thread cutting and self tapping springtites and sems. Dimensions. (227)

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Electroforming. Gar Precision Parts, Inc., 4 pp, ill. Process permits exact reproduction of intricate details on sheet or complex forms using permanent or expendable mandrels. (228)

Custom Molding. General Electric Co., 6 pp, ill, No. CDP-661. Folder describes company's mold-making facilities at Decatur, Ill., and Taunton, Mass. (229)

Government Specification Products. E. F. Houghton & Co., 7 pp. Handy reference listing of Houghton production meeting government specifications. Listing includes specification numbers, description and name of approved Houghton product. (230)

Tube Mills. The Yoder Co., 65 pp, ill. Pros and cons of operating a tube mill, plus detailed information on the process. Also technical data on standard and other equipment. (231)

Inspection • Testing • Control

Industrial Radiography. Atomic Energy of Canada Ltd., Commercial Products Div. Up-to-date information on non-destructive testing of metals by gamma radiography. (232)

Testing Machine. W. C. Dillon & Co., Inc., 4 pp, ill, No. 2. Complete data on Model L Dillon Universal Tester that tests materials with tensile strength from a few pounds up to 160,000 psi. (233)

Wrattan Filters for Technical Use. Eastman Kodak Co., 343 State St., Rochester 4, N. Y., 78 pp, price 75c. "Kodak Wrattan Filters for Scientific and Technical Use" lists over 100 filters having applications in black-and-white and color photography, and discusses forms and types of filters, their standard uses and care. Write direct to Eastman.

Universal Testing Machines. National Forge & Ordnance Co., Testing Machine Div., No. 501. Specifications, capacities and operating principle of table model universal testing machines. (234)

Materials Controls. Remington Rand, Inc., No. KD367. Describes Kardex system for keeping visible materials and parts inventories coordinated with production. (235)

Tensile Testing Machines. Scott Testers, Inc., 6 pp, ill, No. 50. Shows wide assortment of testing machines for testing tensile strength of materials such as rubber, paper, wire and thread. (236)

Ultrasonic Tester. Sperry Products, Inc., 8 pp, ill, No. 50-105. Industrial applications of ultrasonic non-destructive testing techniques with the portable Sperry reflectoscope. (237)

Program Controllers. Tinius Olsen Testing Machine Co., 4 pp, ill, No. 48. Describes the new line of electronic controllers for automatic production testing anl research testing. (238)

General

Air Handling Equipment. The Spencer Turbine Co., No. 107-C. Data book on this company's equipment for the handling and use of compressed air. (239)

Low-Temperature Processing. Webber Co., Inc., 4 pp, ill. Freezing chambers for material shrinking, stabilization and production testing. (240)

DESIGNING WITH ALUMINUM

NO. 11

This is one of a series of information sheets which discuss the properties of aluminum and its alloys with relation to design. Extra or missing copies of the series will be supplied on request. Address: Advertising Department, Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, California.

COMBATING CORROSION

ALUMINUM is widely recognized as a light weight material of construction having good mechanical properties and excellent resistance to corrosion. With industry placing increased emphasis on longer equipment life, and therefore on less rapid corrosion deterioration, there has been a strong trend toward replacing less corrosion resistant metals with aluminum alloys. To obtain the fullest benefits from these changes in materials of construction, each installation should be properly designed from the corrosion standpoint so that maximum service life can be obtained.

Why Aluminum Is Corrosion Resistant

Corrosion is essentially the reversion of a metal to its ore under the influence of natural weathering and other accelerating factors. Aluminum owes its comparative immunity to corrosion to the formation of a thin invisible coating of oxide which forms very rapidly over its surface. This oxide is kept in constant repair by the atmosphere, and it usually affords a very high degree of protection to the metal in all except the most corrosive of environments. However, in extremely corrosive environments the protection given by the oxide film may not be quite enough to prevent corrosion completely, and small white deposits of hydrated aluminum oxide may form at weaker places in the surface film. Even here, however, the attack on the metal rapidly comes to a virtual halt due to the additional protection afforded by the corrosion products themselves. Table 1 shows the small decreases in mechanical properties of aluminum alloys exposed to rural, industrial and marine atmospheres for a ten year period.

TABLE 1

RESISTANCE OF WROUGHT ALUMINUM ALLOYS TO CORROSION BY NATURAL ENVIRONMENTS

% Change in Tensile Strength Resulting from Ten Year Tests

Alloy	ATMOSPHERE		
	Rural	Industrial	Marine
1100-H14	−3	−6	−3
3003-H14	−1	−5	−1
2024-T3	−3	−7	−7
Alclad 2024-T3	+2*	+1	+2

**Increase in mechanical properties is due to ambient temperature age hardening*

Data based on information published in ASTM Symposium on Atmospheric Exposure Tests on Non-Ferrous Metals published February 27, 1946.

How to Design for Maximum Corrosion Resistance

The test results shown in Table 1 clearly reflect the excellent corrosion resistance of flat panels of aluminum alloys. However, any highly resistant material of construction will never give the maximum service in a poorly designed structure. Some methods of insuring good design from the corrosion standpoint are outlined below:

Avoiding Crevice Corrosion and Liquid Entrapment Inaccessible places such as sharp re-entrant angles are ideal places for the accumulation of solids and for liquid entrapment. Under such conditions it is difficult for oxygen to circulate freely and repair any damage to a protective oxide film. These places are, therefore, potential trouble spots with even the most highly corrosion resistant metals. Sharp corners must be avoided wherever possible (Fig. 1).

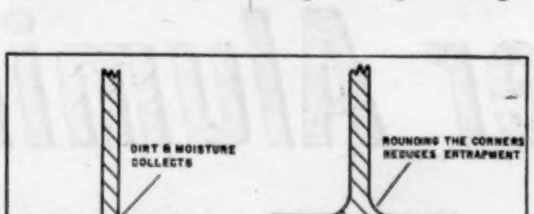


Fig. 1. Reducing entrapment by rounding sharp corners greatly improved corrosion behavior.

In equipment involving the use of liquid solutions, adequate facilities must be provided to insure complete drainage (Fig. 2).

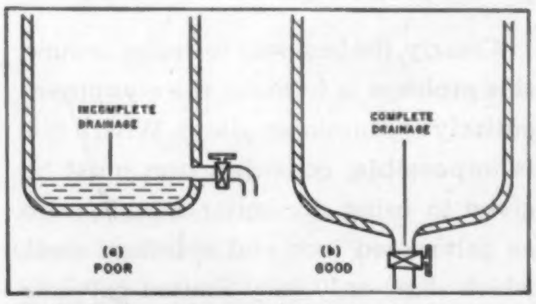


Fig. 2. Design to improve drainage and enhance corrosion resistance.

Welded connections should be used instead of bolting or riveting, and butt welds are definitely preferable to lap welds (Fig. 3).

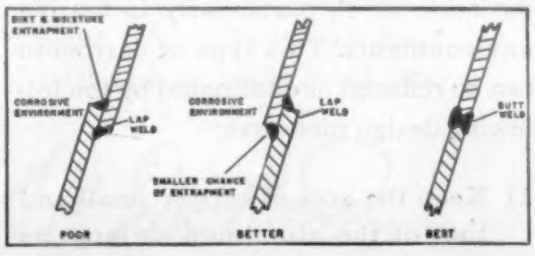


Fig. 3. Design of welded joints from the corrosion standpoint.

Where a bolted connection is mandatory, the crevices should be sealed wherever possible by a mastic compound or by weld metal.

Heat exchangers should be designed to give smooth, non-turbulent flow with a minimum of air entrainment and should be provided with suitably located strainers in the cooling lines to prevent the build-up of deposits at unavoidable local obstructions.

PLEASE TURN TO NEXT PAGE

Every effort should be made to prevent the accumulation of dirt and insoluble matter on aluminum structures. Such deposits and poultice-like material will frequently be the sites of unnecessary corrosion. Low pitch aluminum roofs should be avoided in areas of low rainfall where the washing action of the rains is insufficient to remove wind-blown deposits. Under these conditions a regular hosing down of the structure will greatly extend its service life.

Avoiding Galvanic Corrosion Galvanic corrosion of aluminum in contact with some dissimilar metals can be a serious hazard in a corrosive environment. In most cases, aluminum will suffer accelerated corrosion while partially or completely protecting the other metal.

Clearly, the best way to design around this problem is to make the equipment entirely of aluminum alloys. Where this is impossible, consideration must be given to using dissimilar metals, such as galvanized iron and stainless steel, which show only very limited galvanic activity with aluminum. In most environments contact with these two products is not harmful to aluminum.

However, direct contact with copper, brasses, bronzes and steel can stimulate the corrosion of aluminum to an undesirable level, particularly in marine environments. This type of corrosion can be reduced or eliminated by the following design measures:

1) Keep the area of copper small and that of the aluminum as large as possible. This reduces the overall corrosion and reduces its intensity by spreading it out.

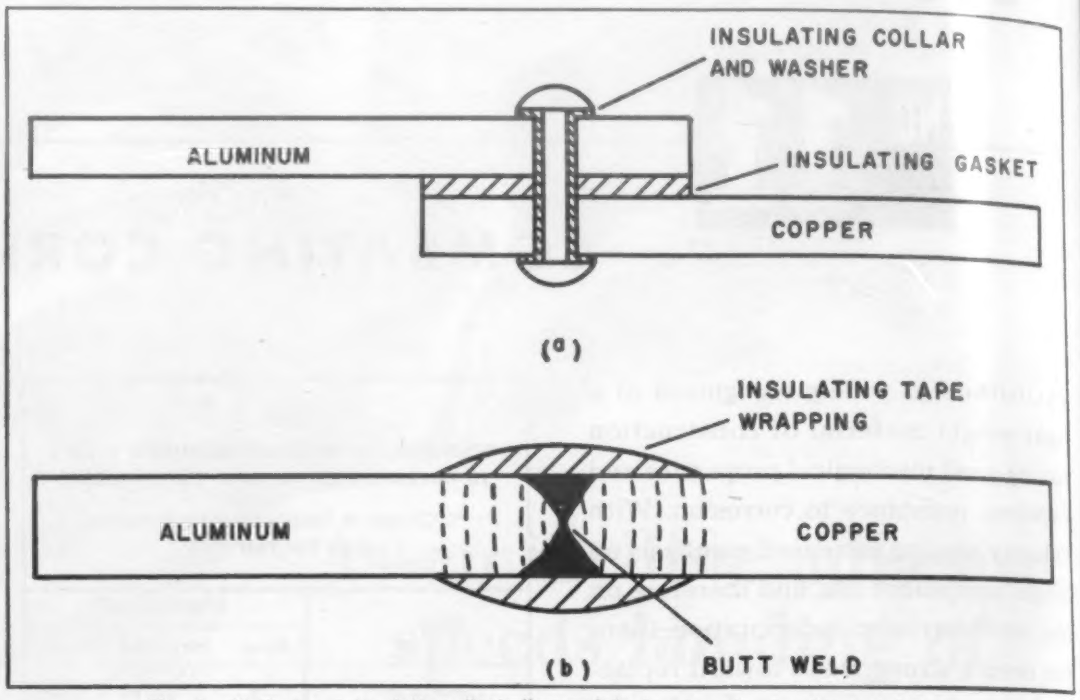


Fig. 4. Methods of insulating dissimilar metals to prevent galvanic corrosion.

2) Paint or protect both the aluminum and the copper or the copper alone. Under no circumstances protect the aluminum alone, because the intensity of corrosion at any discontinuity in the protective coating will be very high.

3) Wherever possible, insulate the copper from the aluminum by insulating gaskets or by wrapping with tape as shown in Figure 4.

Avoiding Stress Corrosion and Corrosion Fatigue Since most aluminum alloys have high resistances to stress corrosion and to corrosion fatigue, proper design practices in operating equipment can further reduce these corrosion hazards to an almost non-existent level. Proper design to prevent both types of corrosion consists of minimizing the stress levels in the equipment. This may be achieved by avoiding stress raisers such as sharp radius bends, small radius fillets, crevices and notches. Residual stresses should be reduced wherever possible by insuring accurate fitting of assemblies, while members carrying the highest design loads can be made extra thick. In this way stresses may be kept to a minimum and the maximum service life can be attained.

The design practices outlined above represent those most commonly applied to obtain the highest degree of corrosion resistance from aluminum equipment. More detailed assistance with design and alloy selection may be obtained through the Kaiser Aluminum sales office listed in your telephone directory, or through one of our many distributors. Kaiser Aluminum & Chemical Sales, Inc. *General Sales Office:* Palmolive Bldg., Chicago 11, Ill.; *Executive Office:* Kaiser Bldg., Oakland 12, California.

One point of view

Share your problems

Recently Solar Aircraft Co. held a conference at its Des Moines plant, setting an example which could be followed by others to great advantage.

The conference brought together representatives of materials producers, fabricators of parts and Solar engineers. The general idea was to show what problems faced Solar in developing its products and to explain trends which are developing.

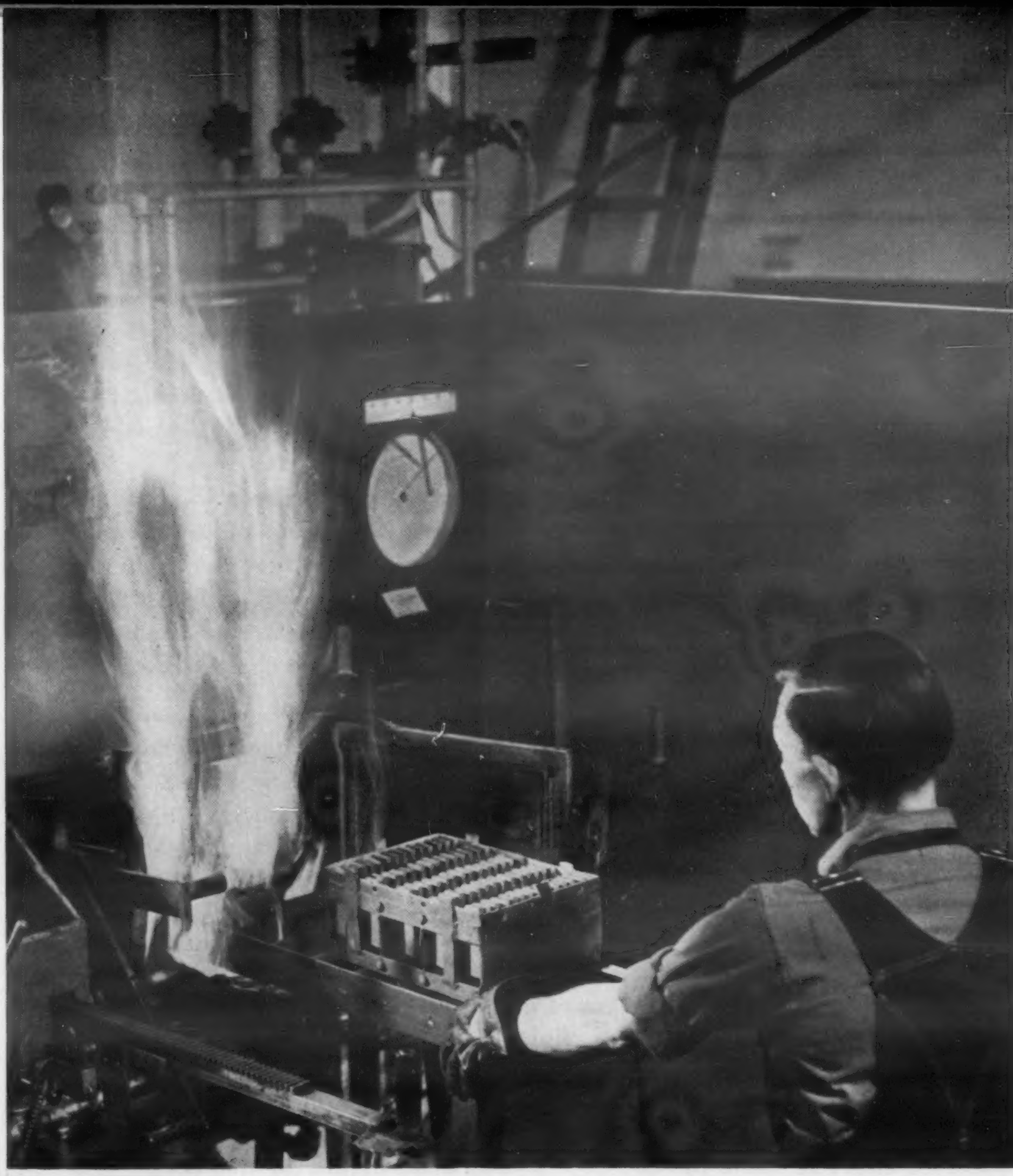
As the meeting developed, Solar's suppliers were told how they had failed—if they had—and where improvement was needed and why. The hope was to attain a higher level of quality today and to prepare for the more stringent demands of tomorrow.

Most companies face similar problems, but usually attempts to meet these problems are on a piecemeal basis. No concerted effort is made to see that a systematic program is prepared and that all elements are informed about what is needed.

While the cry for more engineers is getting louder every day, it seems to me that much engineering talent is being wasted through misuse. An old adage states that many hands make light work. That same principle could be applied to brains. The more people you have working on your problems, the greater is your chance of solving them. Most suppliers of materials, castings, forgings, finishes or other basic ingredients of your product have trained personnel who could be of help. Use them.

Don't be afraid to admit you have troubles. We all do. At the same time, change your attitude toward many of your suppliers and consider them as arms of your own engineering departments. They can be something more than organizations trying to make a sale. Of course, they want to sell, but you'd be surprised at how many want to help you and can help you.

T. C. Du Mond



Iron powder vanes *are infiltrated with copper to develop the required strength.* *(Thompson Products Co.)*

New Trends in Powder Metallurgy

→ *Metal powder sheet*
→ *High strength steel powder parts*
→ *Slip casting powders*
→ *Centrifugal compacting*
→ *Parts from metallic hydrides*
→ *Powder parts with special structures*

by Herbert B. Michaelson,
Atomic Energy Div., Sylvania Electric Products, Inc.

■ Developments in powder metallurgy within the past few years have shown its flexibility in 1) producing engineering materials having new properties and 2) in providing new economies in fabrication techniques. Although powder metallurgy has usually been associated with the production of machine parts, porous bearings, filters, cutting tools and iron cores, powder methods are now finding other applications. Recently developed techniques include the continuous rolling of strip or sheet directly from metal powder, the development of special structures for high hot strength and resistance to annealing, the sintering of high-strength steels, the fabrication of sheet by flame spraying, the preparation of porous, corrosion-resistant sheet, and the sintering of reactive metals, such as zirconium, from their hydrides.

Important advances have also been made in plating sintered parts for desired finish and corrosion protection. Other new techniques which have attracted attention recently include centrifugal compacting for uniform density, and slip casting of metal powders in economical plaster-of-paris molds.

Rolling sheet from powder

This method, originally developed in Germany, has the economic advantage of requiring few rolling and annealing operations. Copper, cupro-nickel, brass, bronze, Monel and stainless steel powders have been rolled into sheet by this new technique. Bimetallic strip for bearing, friction and electrical contact applications have also been produced.

The initial part of the process consists of conveying the metal powder from a feed hopper to a set of rolls. As the powder passes between the rolls, the particles are compressed and interlocked into a porous sheet or strip, which is sintered, re-rolled and annealed to obtain the desired properties. The rolling

TABLE 1—PROPERTIES OF SHEET ROLLED DIRECTLY FROM POWDER

Material	Condition	Thickness, mils	Density, gm/cu cm	Ten Str, 1000 psi	Elong, %	Ref
Copper	Rolled and sintered once	16.5	8.1	10.7	15.0	(1)
Copper	Rolled, sintered, and re-rolled & annealed once	11.8	8.8	16.3	32.0	(1)
Copper	Rolled, sintered, and re-rolled & annealed twice	9.5	8.9	29.5	25.0	(2)
85-15 Brass	Rolled, sintered, re-rolled and annealed twice	6.9	8.02	22.0	3.3	(2)
72-28 Brass	Rolled, sintered, and annealed twice	8.1	8.17	25.7	5.3	(2)
18:8 Stainless Steel	Rolled, sintered, re-rolled three times	9.0	7.83	108.0	33.0	(3)

mills and the sintering and annealing furnaces can be arranged for continuous fabrication of sheet.

Porosity can be controlled by variation of the roll gap and by the extent of sintering. Thickness of the rolled material also depends on the roll gap and, to a lesser extent, on the roll speed, particle size and other characteristics of the powder. Maximum thickness obtainable depends on green strength of the powder, since the sheet must be strong enough to be passed into the sintering furnace. In order to produce sheet with a good edge, guides to restrict the lateral flow of powder can be placed in the roll gap. The green rolled sheet can be sintered in a short time because it can be quickly brought to temperature. The process is highly flexible and sheet can be fabricated in a wide range of physical properties.

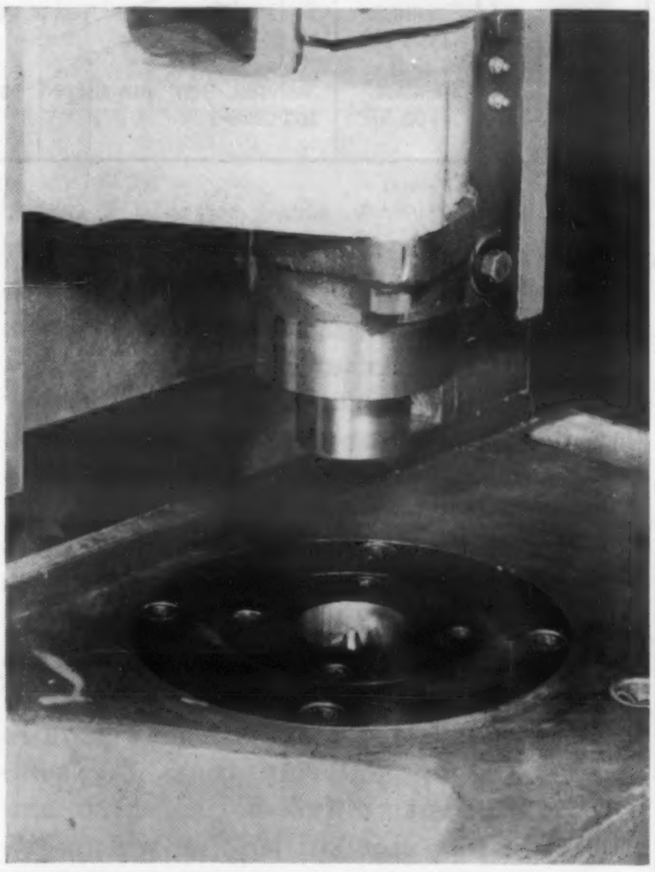
The structure is somewhat different from that of sheet rolled from cast material. Sintered sheet can be made with randomly oriented grains, whereas sheet rolled from cast material acquires a preferred orientation which tends to impart directional properties. Uniform mechanical properties are desirable in sheet materials since they reduce earing when the sheet is deep drawn.

The powder rolling process is also adaptable to the fabrication of alloy sheet from mixed powders. A blend of copper and zinc powders, for example, can be rolled and sintered into brass. Table 1 shows some typical properties of strip or sheet produced from powder, and includes data on some experimental 18:8 stainless steel strip made at Sylvania.

Steel powder parts

The production of steel powder parts with well-developed physical properties has widened the scope of applications for small parts. High mechanical properties can be obtained from either mixed or pre-alloyed powders.

Sintered ordnance parts such as revolver cylinders, gun sears and accelerators can be made by the Isthmian process[4] with surface hardness as high as Rockwell C 48-53 and in the range of 98.4% of full density. Powder mixtures of annealed electrolytic iron, carbon and ferro-manganese are blended in proportions to give final approximate compositions of SAE 1060 (Class A steel) or SAE 1080 (Class B steel). After the compacted powders are sintered, Class A parts will contain about 0.1% carbon and are soft enough for coining to high density. Subsequently the parts are carburized, quenched and tempered. If 0.1% carbon in the core is specified, the carburizing is carried out only long enough for surface hardening, which provides about 0.8% carbon in a hard, wear-resisting case. Larger parts are made of Class B steel, starting with a higher percentage of carbon in the mixed powder to avoid the necessity of a lengthy through-carburizing process. The resultant carbon content in the



Punch and die *ready to mold a metal powder part.* (Kux Machine Co.)

Steel powder parts *now being produced with well-developed physical properties have widened the field of application for small parts.*
(Hydraulic Press Manufacturing Co.)

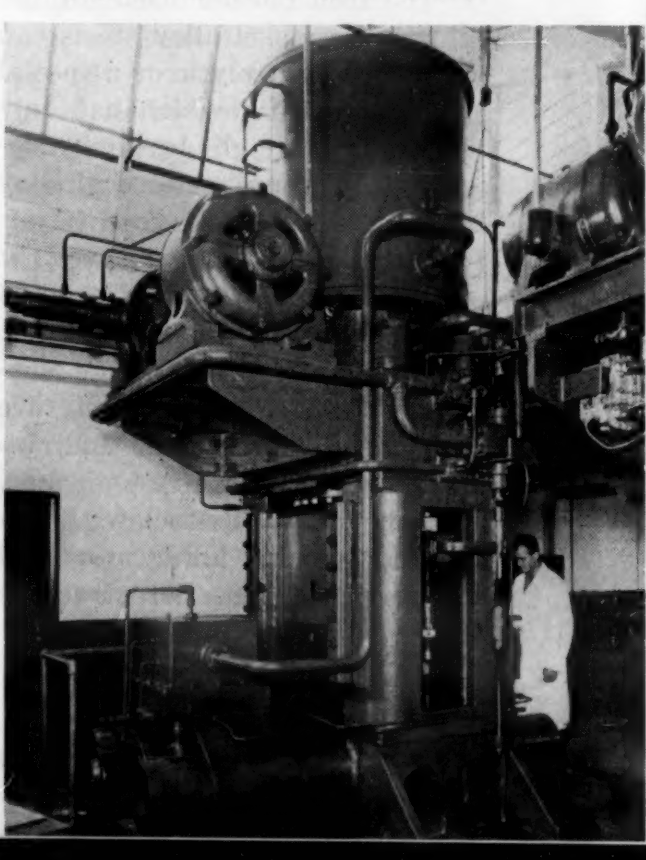


TABLE 2—TYPICAL PROPERTIES OF STEEL POWDER PARTS

Material	Condition	Density	Ten Str, 1000 psi	Elong in 1 in., %	Rock-well Hard-ness	Ref
SAE 1080	Sintered from mixed powders, coined, carburized and tempered	98.0[a]	156	13.0	C 35	(4)
SAE 1060	(same as above)	95.5[a]	198	4.0	C 37	(4)
Cr-Ni alloy steel	Sintered from mixture of electrolytic iron with 7.5% of 80 Cr-20 Ni	6.68[b]	105	2.2	B 98	(5)
Cr-Ni alloy steel	Sintered from mixture of electrolytic iron with 7.5% of 50 Cr-50 Ni & 1% C	7.10[b]	101	4.6	B 90	(5)
Stainless, Type 302	Sintered from pre-alloyed powder	6.40[b]	49	15.0	B 41	(6)
Stainless, Type 302	Sintered from pre-alloyed powder and coined	6.89[b]	63	21.0	B 60	(6)

[a] *Percent.*
[b] *gm/cu cm.*

core is about 0.6% after sintering. The parts are then coined, but because of their hardness do not reach as high a density as Class A steel. Typical properties, depending on carbon content and extent of heat treating, are shown in Table 2.

High-strength steels are also made from combinations of chromium, nickel, iron and graphite powders. Since mixtures of primary metal powders require long sintering times for sufficient diffusion, a chromium-nickel alloy powder which diffuses more rapidly into the iron powder can be used. When size and shape of the alloy particles are about the same as those of the iron powder, ordinary techniques for sintering alloy steels can be employed.

The iron powder used for the chromium-nickel alloy steels can be either electrolytic or a special reduced powder which has only about 0.3% weight loss in hydrogen. Typical proportions of alloy powder which yield good physical properties are 2.5 weight percent of 80 Cr-20 Ni or 7.5 weight percent of 50 Cr-50 Ni. Approximately one percent carbon is added and the mixture pressed at about 50 tsi and sintered one hour in dry hydrogen. Sintering in dissociated ammonia yields lower physical properties. The microstructure of finished parts indicates a fine dispersion of the chromium-nickel alloy particles.[5] Property data are given in Table 2.

Prealloyed stainless steel powders are available in standard 18:8, stabilized 18:8 and higher nickel stainless alloys.[6] The compositions of these powders are the same as those of conventional stainless steel sheet and bar stock. These powders can be compacted at pressures as low as 30 tsi and sintered as low as 2100 F. Applications include automotive parts, tubing and bushing in industrial meters which measure corrosive fluids, small gears and levers. Some properties of coined and sintered parts are given in Table 2.

Materials with special structures

One of the important features of powder metallurgy is the fabrication of special structures which cannot ordinarily be done by melting and casting or other conventional methods of metal fabrication. By hot pressing metal powders, for example, one can obtain small grain size because the crystallites do not grow rapidly at the temperatures used. Materials of high mechanical properties can be made in this way. Uniform structures having well-dispersed graphite or oxide particles can be made by the powder method.

One example is the uniform dispersion of oxide particles around the grain boundaries in aluminum fabricated by the Swiss SAP process. The envelopes of oxide which originally cover each particle seem to restrict grain growth during hot pressing and give better mechanical properties.[1] At oxide contents of about 8 to 16%, the fine grain size provides higher hardness values than are obtainable with wrought aluminum and better tensile strength at high temperatures.

The improved mechanical properties are obtained by compacting heavily oxidized aluminum powder of very small particle size at 25 to 50 tsi in air at about 1000 to 1100 F. Sintering is followed by hot pressing in the range 900 to 1100 F and extrusion at the same temperature. The extruded material can then be either forged or rolled to final shape. Typical tensile strengths at room temperature for about 13%-oxide content are 50,000 psi, with a yield strength of 32,800 psi and 8% elongation. Tensile strength is 30,000 psi at 750 F and 23,000 at 1100 F. At temperatures above 600 F, the strength is superior to that of commercial wrought aluminum alloys. Creep strengths are shown in Table 3.

Of particular interest is the retention of properties after high temperature soaking. After soaking for one year at 925 F, the ultimate tensile strength of SAP with 13% oxide is reported

TABLE 3—CREEP STRENGTH OF SAP CONTAINING 13% OXIDE

Temp, F	Stress for 0.2% creep, after one month, psi
300	26,900
400	17,450
480	12,550
570	11,650
660	11,200
750	10,750

to the 49,000 psi at room temperature. After soaking for one month at 925 F, the tensile strength at that temperature is 14,000 psi.

Since the oxide is very finely divided in SAP, it does not produce the high rate of wear in cutting tools, which might be expected because of its alumina content. An SAP composition containing 13% oxide has a Brinell hardness of about 93, and its wear resisting properties are about the same as those of normal aluminum alloys. The SAP compacts can be produced with enriched surface oxide to give considerably higher surface hardness. For higher wear-resistance or smaller thermal expansion, SAP may be also alloyed with other metals.[1]

Magnesium and magnesium alloys hot-pressed and extruded from oxide-coated powders resembling SAP aluminum powder will retain their hardness and strength after heat treatment. Although these extrusions are not commercially available, their use in certain applications where high mechanical properties are needed may justify the cost.

Another example of special structures made by powder metallurgy is the evenly dispersed graphite in sintered iron piston rings manufactured in Germany. This material can now be produced with the same type of phosphide eutectic structure found in gray cast-iron piston rings. In the powder metallurgy product, fine particles of either nodular or laminar graphite are distributed more uniformly than is possible in cast material. In starting cold engines, the presence of graphite is said to be important in reducing wear before liquid lubrication begins. In addition, the sintered material is claimed to have greater ductility than cast iron for a given tensile strength. At a tensile stress of 113,000 psi, elongation of a powdered iron piston ring material is 0.4%.[7] This type of material has been used for rings in gasoline and diesel engines.

TABLE 4—PROPERTIES OF BRONZE-INFILTRATED IRON

Density of Iron Skeleton, %	Infiltrated Density, %	Ult Ten Str, 1000 psi	Yld Point,* 1000 psi	Elong 1 in., %	Rockwell Hardness
90	99.8	102	84	5	B 98
90	91.5	30	29	2	B 76
85	99.7	102	94	4	B 100
85	91.5	82	80	3	B 87
80	99.3	82	75	4	B 93
80	85.5	68	67	2	B 75
75	99.3	80	69	5	B 89
75	84.7	58	58	2	B 66

* *Determined by dividers.*

A further example of special structures is high-strength infiltrated iron or steel. By infiltration the mechanical properties of a porous iron compact can be raised markedly without several coining and re-sintering steps. Moreover, good physical properties can be obtained by this process, even in parts of complicated shape, which ordinarily have density variations in the as-coined condition.

Infiltration with copper gives a structure which may be described as iron particle agglomerations embedded in a matrix of copper. A typical value of room-temperature tensile strength of such material is 84,000 psi, compared with 17,000 psi for the skeleton of sintered iron which had not been infiltrated. Bronze infiltration has also been established in industrial practice, and some fabricators are making brass-infiltrated iron. Some properties of bronze-infiltrated material are shown in Table 4.

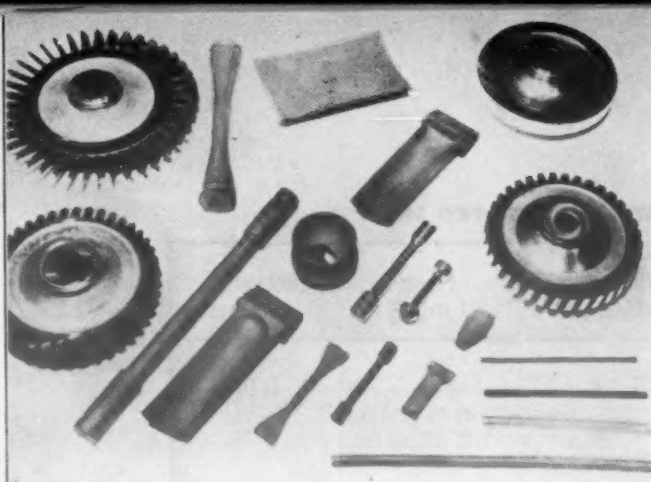
One application of copper-infiltrated iron has been jet engine compressor blades. Bronze or brass infiltration is used for various types of structural parts. Lead is a suitable infiltrant for bearings in which the copper-lead material is subsequently sintered to a copper-plated steel backing.

Plating powder parts

Although sintered parts usually have a velvety appearance, the surface can be plated for better resistance to corrosion or abrasion, or for decorative purposes. Silver or copper plating will give low electrical resistance, and a plating of tin will increase solderability. Chromium, nickel, cadmium, zinc and other metals are used for their appearance and durability.

Choice of the best method of plating a metal powder part is determined by the degree of surface porosity.[8] Materials more than about 95% dense have only a few isolated pores on the surface and can be plated by the procedures used for forged or wrought parts. With materials having about 85 to 95% of theoretical density, the surface pores are usually closed first either by impregnation, mechanical working, or heat treatment. High-porosity parts, which may have densities as low as 40%, usually do not require plating. Examples are bronze oil-containing bearings and steel filters. If it becomes necessary to protect highly porous parts from corrosive liquids or atmospheres, special plating methods can be used.

Spotting-out is one of the chief difficulties in plating of any porous compact. Acids and salts from the electrolyte tend to be trapped in the interconnecting pores of a sintered compact,



***Metal powder parts** developed for service in the high temperature field.*

and unless the liquids are removed or neutralized, they tend to exude from the surface pores, causing the plated finish to discolor or flake off. One method of preparing ferrous parts for plating is to close the pores by infiltration with copper, lead or tin. Copper provides a highly conducting surface for subsequent deposition of chromium or nickel. Porous parts may also be prepared for plating by vacuum impregnation with thermosetting polyester styrene. Such parts are claimed to be pressure tight to over 5000 tsi and usable at temperatures up to 350 or 400 F.

High corrosion resistance is said to be obtained with powder parts infiltrated with resins. Sodium silicate types may be used either with or without semicolloidal metal fillers. Other combinations used include styrene with dehydrated castor oil or linseed oil. Porous iron compacts closed with such sealants and plated with cadmium are claimed to withstand 300 to 700 hr of salt spray.[8]

Another process consists of electroplating the unsintered compact, which is then given a neutralizing dip and sintered in the usual way. As the surface pores tend to close in the last stages of sintering, the plating metal may at the same time diffuse into the surface, giving a strongly adherent plating. Alloyed surfaces can also be prepared by plating with layers of copper and tin or with copper and nickel and following with sufficient heating to diffuse the layers. The resultant alloy platings will then consist of bronze and Monel, respectively.

Brass parts can be prepared for sintering by polishing and buffing to close the surface voids. After the part is copper plated to one mil or less, it is re-buffed, and subsequently plated with nickel and chromium. The copper coating may be omitted if a perfect surface is not required for the finished part.

Sintering from hydrides

Some metals can be sintered conveniently by decomposition of a powdered hydride into metal and hydrogen. Metallic hydrides are generally safer to handle than degassed powdered metals of the reactive type, such as zirconium or titanium. After compacting, the hydride briquets are sintered either in vacuum or in an enert atmosphere. Since the metal forms during the dissociation of the hydride, the metal itself has not been cold worked. There is a tendency for hydride compact to sinter more quickly than metal compacts because the metallic atoms apparently acquire a higher mobility as the hydride decomposes. Zirconium hydride compacts, for example, sinter to high densities at lower temperatures than do zirconium powder compacts. The ductile sintered product is characterized by fine grain size, low gas content and good corrosion resistance.

Optimum sintering conditions for −325 mesh zirconium hydride are 50 tsi compacting pressure and three hours sintering at 2280 F. Typical properties are: density, 6.59 gm/cu cm; hardness, Rockwell B-92; tensile strength, 95,000 psi; and elongation, 5.3%.[11] The sintered material can be machined or surface ground and can be hot-worked readily in air up to 1300 F. Steel or copper jacketing is used for prolonged hot working.

Titanium and titanium alloys can also be prepared from their hydrides. As in the case of zirconium, the hydride sinters to high densities far more readily than does the metal powder. The presence of small quantities of hydrogen causes embrittlement of titanium, and care must be taken to remove the last traces if ductile parts are to be obtained.

Table 5 shows densities obtained in recent British work[1] on sintering of hydrides with or without additions of chromium or molybdenum. By contrast, titanium metal powder required three sintering and coining treatments to attain a density of 4.36 gm/cu cm. The powder metallurgy of titanium and its hydrides is still generally in the developmental stage.

Porous materials

The inherent porosity of sintered materials is utilized in the production of gasoline filters, oil-less bearings and bushings in automotive and aircraft applications. Shapes commonly produced are disks, plugs, hollow cylinders or sheet. Properties of sheet are discussed in a separate article in this issue. (See page 98.)

These porous parts are used not only for filtering solid particles from liquids or gases but also for diffusing air in the aeration of liquids, for separating liquids having different

TABLE 5—DENSITIES OF TITANIUM AND TITANIUM ALLOYS PREPARED FROM HYDRIDES

Alloy	Sintering Treatment		Shrinkage, %	Density of Sintered Part	
				gm/cu cm	% of Theoretical
Unalloyed	2375 F	8 hr	13.3	4.42	98.4
10% Cr	2375 F	4 hr	12.7	4.50	96.5
10% Mo	2200 F	20 hr	—	4.60	96.7

surface tensions, and for flame arresting, in which the mass of the filter dissipates the heat of the flame but allows combustion gas products to pass through.

The increase of such applications in recent years has led to the use of new corrosion- and heat-resistant materials in porous parts, particularly stainless steel, nickel and Monel. Porous 18:8 austenitic stainless steel filters for example, have advantages of high resistance to thermal and mechanical shock, good corrosion resistance, operation at temperatures as high as 925 F, and higher flow rates for a given pore size than many other sintered materials.

The many applications of stainless steel filters include separation of solid catalyst particles from fluidized catalysts in chemical plants; beaker filters, filter crucibles and aerators in laboratories and pilot plants; and filtration of photographic processing solutions.

Another recent use of stainless steel powder is the fabrication of porous gas turbine blades.[1] Porous nozzle vane guides have been made from this material in a design which utilizes "effusion cooling". This component operates at the highest blade temperature in the gas turbine but is not subjected to high centrifugal forces, as are rotating blades. The nozzle vane guides can withstand stresses of approximately three or four tons per square inch at 850 F. The perimeter of the blade is highly porous and the cooling liquid or air is pumped through channels in the core of the blade and into the porous skin. The fluid cools by conduction through the pores and, if it is a liquid, it cools the blade further by vaporization. The porous steel can be strengthened if necessary by means of gauze or wire.

Other recent developments

Powders can be cast in complicated shapes to avoid subsequent costly machining operations. One process reported by NACA is freeze casting, wherein a rich slip of a refractory powdered material, such as titanium carbide, is prepared with a small amount of binder. This casting is frozen to retain the shape of the cast, dried by sublimation, and then sintered in the conventional way. The process has been applied to the fabrication of turbine blades. A somewhat similar method is British patent No. 694,203 on slip casting of tungsten or molybdenum powders. A slightly acid slurry of the metal powder is poured into a plaster-of-paris mold and allowed to dry. The form is then removed and sintered in hydrogen. Molybdenum crucibles have been prepared by this method. Advantages are low cost of fabrication and ease of producing parts of special size or shape. This method shows promise for other types of metal powder products.

Centrifugal compacting has been used for heavy powders where uniform density of the finished product is important. One application is the production of four-pound tungsten carbide bullet cores. Aluminum molds are charged with the carbide powder and centrifuged to give compacting pressures of about two tons per square inch. The centrifugal force appears to act on each powder particle, decreasing the inter-particle friction and providing uniform density. The centrifuged parts are removed from the mold and sintered in the usual way. Final densities and strengths are about the same as with conventional pressing methods. This process is suitable for dense powders and for the production of parts having cross sections larger than about 1/4 in.

A new way to accelerate the reactions during powder metallurgical processing is a French process called "activated sintering", which is claimed to produce high elongation in iron compacts comparatively low density after short periods of sintering.[1] A small quantity of a halide salt, such as amonium fluoride or chloride is placed in the green iron powder compacts, which are sintered in hydrogen in a closed compartment. During sintering, a film of iron fluoride forms on the particle surfaces and aids in the formation of rounded pores. The fluoride then decomposes and diffuses out of the compact. Elongations of over 10% at fracture are claimed with an iron compact having a density of 5.7 gm/cu cm, and the test pieces can be twisted through several complete turns.

Flame spraying is a recent development which has been applied in the manufacture of sheet from powders of copper, zinc, aluminum, stainless steel, Kanthal, and other materials. A flame spray gun operated with fuel gases such as acetylene or propane can be used to spray both sides of a fine wire mesh carrier.[9] The process is said to be economically feasible if odd shapes and/or sizes are needed, and is suitable for the manufacture of porous sheet materials.

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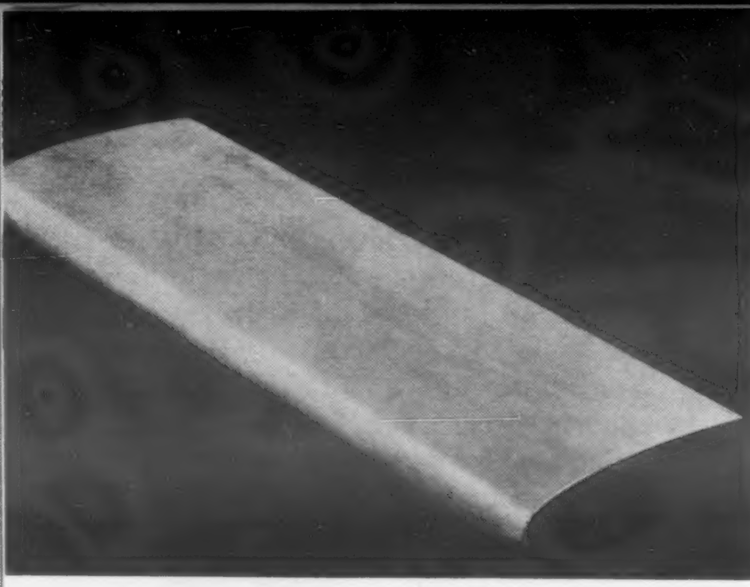
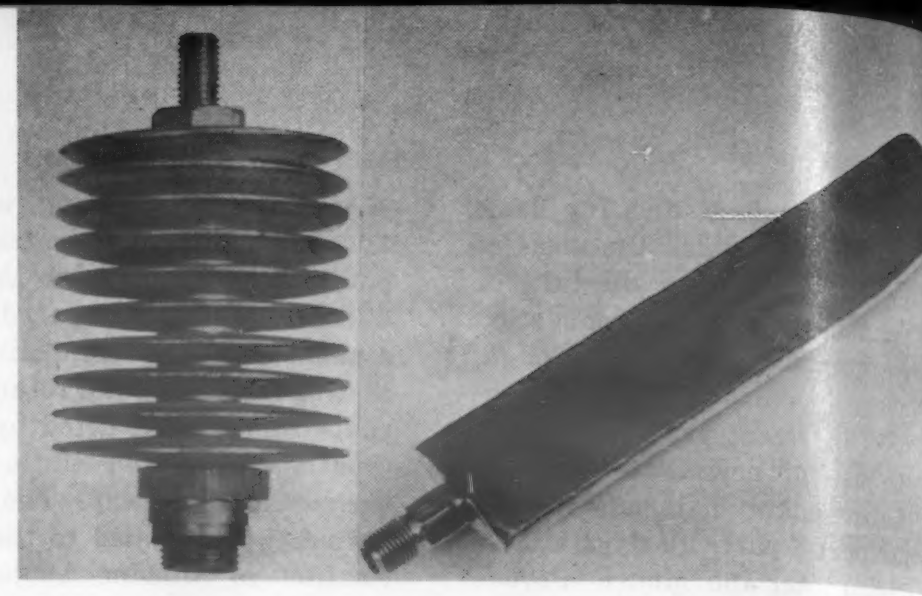
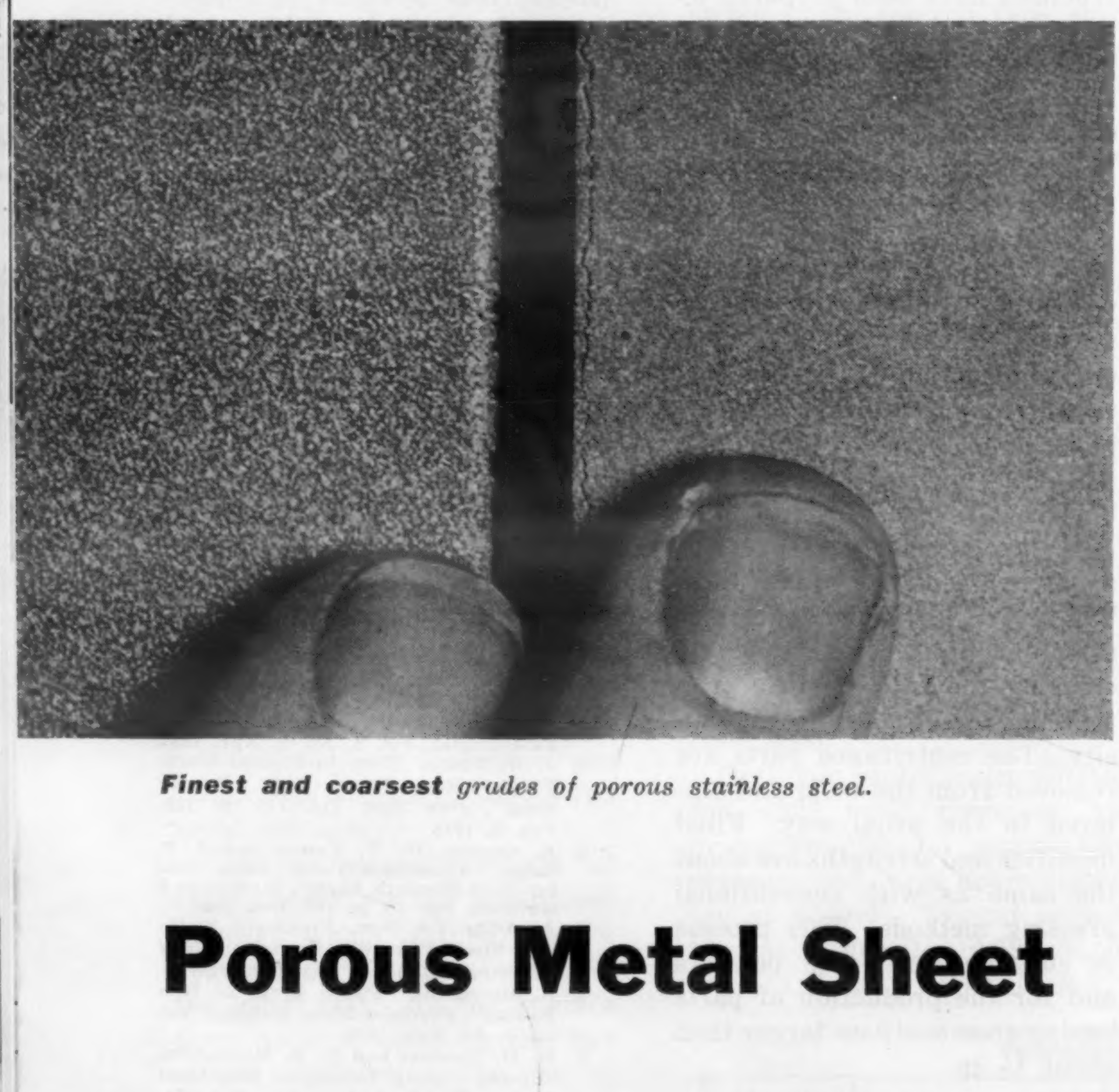


Leading edge section *of aircraft made from porous metal sheet for de-icing.*



Filter elements *typical of those made from porous metal sheet.*

These parts made from—



Finest and coarsest *grades of porous stainless steel.*

Porous Metal Sheet

Controlled permeability plus resistance to heat and corrosion make metal powder sheet materials useful for special applications.

by John B. Campbell, *Associate Editor, Materials & Methods*

■ Heat- and corrosion-resistant metal sheet that is 1) porous enough to pass liquids and gases at low pressure drops, 2) uniform enough for precision applications, 3) strong enough to withstand sizeable pressures, and 4) ductile enough to be formed into useful shapes is now being made by several companies for specialized chemical and aircraft applications. Here are the facts on these specialty porous sheet materials as supplied by the leading producer, Micro Metallic Corp., located in Glen Cove, N.Y.

What it is

Metals available — Austenitic stainless steels (Types 316, 304 and 347) are currently most important. Nickel, Monel, other stainless steels (Types 309, 410, 430, 446 and Carpenter 20) and Haynes Alloy-25 are also standard. Platinum, gold, silver, tantalum and other metals and alloys (which can be obtained in powder form) are available on special order. Porous aluminum sheet has just recently been developed and is expected to be particularly useful in aircraft applications.

Pore size—Seven standard porosity grades (see accompanying table) are currently available. They range from 5 to 165 microns, with 20 and 35 the most commonly used grades. Figures given are "mean pore size"—a quantity that is calculated in such a way that it can be said that half of a fluid flows through pores larger than, and half through pores smaller than, the

mean pore. Manufacturing control is such that over 98% of all pores are claimed to be greater than one-half the mean pore size, and the largest pore is claimed to be generally not more than twice the mean pore size.

Size—Standard is 18 x 48 in., but lengths up to 72 in. have been produced, and lengths up to 100 in. can be produced with present equipment.

Thickness—Standard range is 1/16 to ¼ in., with 1/16 in. most commonly used, but thicknesses as low as 0.010 and as great as 2 in. have been produced with present equipment. Tolerances on thickness are —0.010 + 0.022 in. on 1/16-in. sheet of ordinary grades. On grade X the tolerance is ±0.005 in. or, on special order, as low as 0.002 in.

Flow capacity—For a given pore size, these materials have high flow capacity at low pressure drops, compared with other porous media. See accompanying table and graphs.

Strength — Minimum tensile strength ranges from 15,000 psi for fine grades to as low as 6000 psi for coarse grades. Approximate modulus of elasticity ranges from 1 x 10^6 psi for the coarsest grade to 3 x 10^6 for the finest grade. Shear strength ranges from 20,000 to 40,000 psi. Strength and rigidity of porous metal sheet may be increased by pressing or by sintering in contact with perforated back-up plates. A standard pressed grade of stainless steel grade (X) is available; it has a minimum tensile strength of 25,000 psi and a modulus of elasticity of approximately 15 x 10^6. Finer grades are often pressed for special uses, and tensile strengths as high as 40,000 psi may be obtained. Rigidity of large pieces in assemblies is generally increased by means of flanges and cross ribbing.

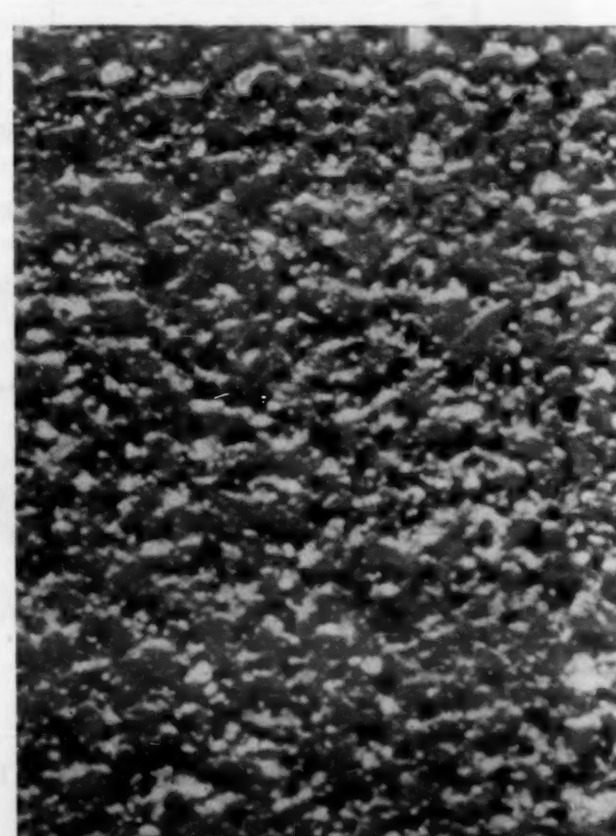
Surface finish — Low-permeability stainless steel sheet is similar in appearance to solid stainless steel having an ordinary mill finish, but the granular surface of the material is easily apparent in high-permeability sheet (see photographic comparisons). Sheet with a higher finish, but lower flow capacity, can be obtained by a pressing operation (e.g., grade X).

Corrosion resistance — In selecting the metal to be used in a specified chemical environment, it is necessary to apply known corrosion rates, not to the thickness of the sheet, but to the thickness of the bonds between the individual particles within the sheet. For the fine grades, these bonds may be less than 0.0005 in. across. Hence, the metal selected must be almost completely inert to its environment.

Cost—Cost of porous stainless sheet varies from a price comparable with woven wire cloth for some grades up to as high as $0.58 per sq in. (about $84 per sq ft) for others. Micro Metallic also makes finished filter units ranging in cost from less than $14 per sq ft to more than $100 per sq ft for special units in small quantities.

Formability — Porous metal sheet can be blanked, sheared, rolled and, to some extent, drawn or dished. Drawing is ordinarily limited to forming spherical sections from 1/16-in. sheet, and maximum depth of draw recommended is two-thirds the diameter of the flat sheet. Minimum i.d. for cylinders rolled from stainless steel sheet of interme-

Surface *of a porous stainless sheet that has been pressed (44X).*



How It's Made

Micro Metallic uses a special patented process to make its porous metal sheet. Metal or alloy powder is deposited in a flat layer of uniform thickness. Particle size range of the powder is selected to provide the final pore size desired. No binder is used at any stage of the process.

The layer of powder passes through a furnace where it is subjected to a temperature just below the melting point of the metal or alloy. Here, bonds develop at points of contact between adjacent particles probably due to the migration of layers of atoms. From the furnace emerges the finished porous metal sheet.

Where stronger porous sheet is needed, one of two techniques is used:

1. A sintered sheet is compressed by a calendering operation and resintered to develop additional bonds at the new contact areas. Calendered sheet retains uniform pore size but has less flow capacity than uncalendered sheet of the same pore size. The pressed sheet also has a smoother surface and is therefore more suitable for aerodynamic use. Properties of a pressed stainless sheet, grade X, are given in this article.

2. A perforated metal backing plate is applied to a sintered sheet. This is done by laying the sintered sheet on a perforated plate of similar composition and welding together the assembly by passing it through the sintering furnace. When correctly selected, the back-up plate does not appreciably change flow capacity, since the structure of the porous sheet provides for good lateral flow.

diate porosities are: 3/16 in. for 1/32-in. sheet, 3/8 in. for 1/16-in. sheet, 1½ in. for ⅛-in. sheet, and 5 in. for ¼-in. sheet.

Machinability — The porous metal can be machined in much the same way as solid metal, and a continuous curling chip is obtained. Due to the "burring" effect on individual particles, however, metal tends to smear over adjacent pore openings, and the permeability of a machined surface is greatly reduced. Finish grinding has an even greater pore-closing effect; permeability may be reduced 95% or more. Where the surface to be machined is not intended to transmit fluid, the pore-closing effect is not important. Where the surface to be machined *is* to transmit fluid, pore-closing may be avoided by impregnating the structure with a synthetic resin prior to machining and dissolving out the resin after machining.

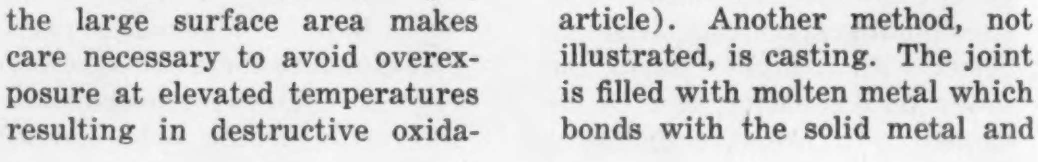
Weldability—Inert-gas-shielded tungsten arc welding is recommended. Without inert gas, the large surface area makes care necessary to avoid overexposure at elevated temperatures resulting in destructive oxidation (see "corrosion resistance"). Porous sheet is ordinarily butt welded in a single pass, and is not adapted to fillet welding. It can be welded to solid sheet or to other porous sheet. Other joining methods being used successfully include riveting, bolting, press-fitting and spinning (see drawings elsewhere in this article). Another method, not illustrated, is casting. The joint is filled with molten metal which bonds with the solid metal and solidifies within the pores of the porous metal sheet.

Plastics, Too

Where porous metal filters can't stand up against a severe corrosive environment and temperatures are below 500 F, porous plastic filters may be the answer. Micro Metallic's sister company, the Porous Plastic Filter Co., uses similar powder metallurgy techniques to make sheet, rod and tubing, as well as finished filter elements, from fluorocarbon, PVC and other plastic powders. This company is also making filters from woven Teflon cloth.

PROPERTIES OF POROUS STAINLESS STEEL SHEET

PROPERTY \ GRADE (proprietary designation)		C	D	E	F	G	H	X
Mean pore opening	microns	165	65	35	20	10	5	15
	in.	0.0065	0.0025	0.0015	0.0008	0.0004	0.0002	0.0005
Tensile strength (min), psi		6000	9000	15,000	15,000	15,000	15,000	25,000
Modulus of elasticity (approx), 10^6 psi		1	1	1.5	2.5	2.7	3	15
Voids content (approx), %		55	50	50	50	50	45	20
Min flow of clean air at 1 psi differential, CFM/sq ft (⅛-in. thickness)		990	475	220	82	41	28	3.2
Min flow of clean water at 1 psi differential GPM/sq ft (⅛-in. thickness)		180	120	20	8	3.5	1.5	1.2
Standard available thickness range, in.		⅛–½	⅛–½	1/16–½	1/16–⅜	1/16–¼	1/16–¼	1/16–⅛



Joining techniques recommended for porous metal sheet.

Where it's used

Filtering liquids and gases. The strength, heat resistance, corrosion resistance, and low pressure drop characteristics of these porous metal sheet materials make them preferable to paper, cloth, wire cloth or ceramic filters for many uses.

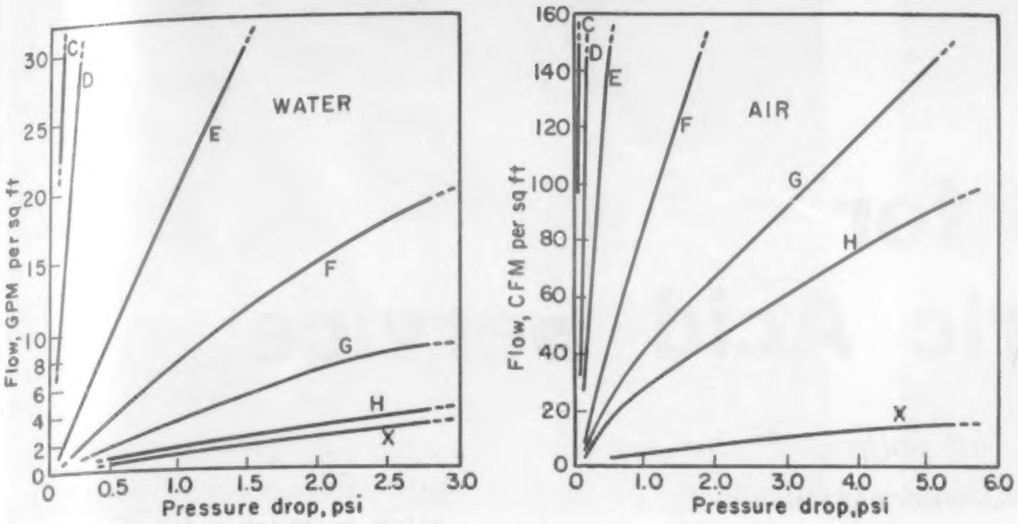
Because of the tortuous passage through the sheet, many undersize particles are trapped by impingement. For example, sheet with a mean pore diameter of 65 microns will remove 98% of the beads from a water suspension of 1-micron glass beads. In liquid filtration the largest particle passed by a sheet of normal thickness is about one-third the mean pore size. In gas filtration it is much less; e.g., sheet having a mean pore size of 35 microns appears to remove all particles larger than 0.5 micron. Flow rates ordinarily recommended range from 2 to 5 gpm per sq ft for liquids and 20 to 60 cfm per sq ft for gases. Flow capacities given in this article refer only to clean air and water; lower ranges must be used in practice to allow for the clogging effect of collected solids.

Filter elements include flat and drawn disks, flat and rolled rectangles and rolled cylinders assembled in various forms, including "bayonets", "stars" (vertically corrugated), and horizontally corrugated shapes.

Dispersing gases in liquids. Because of its high flow capacities even in fine grades, porous metal sheet (especially grade G) is being used for aeration and other applications involving the introduction of large volumes of fine gas bubbles into a liquid.

De-icing high-altitude aircraft. Rolled panels of porous metal sheet are being developed for leading edges so that hot air or liquid can be passed through them to prevent ice formation.

For a number of years, the British have used a liquid de-icing system that makes use of porous bronze or, more recently,



Flow capacities of 1/8-in. porous metal sheet, based on clean air and clean water. Flow capacities are double for 1/16-in. sheet, half for 1/4-in. sheet, etc.

the stronger porous stainless steel. In this country, wing leading edges of high-strength porous stainless steel sheet (Type 316, grade X) have been applied to a gas-turbine-powered plane that uses compressor bleed air at 600 F for de-icing.

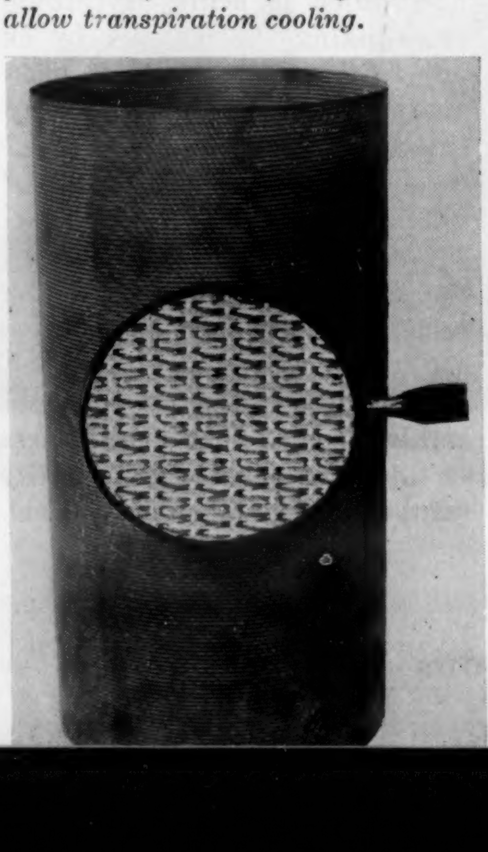
Boundary-layer control for aircraft. One way to improve the low-speed flight characteristics of aircraft (as in landing or taking off) is to eliminate the more or less static "boundary layer" of air that forms immediately adjacent to the lift surfaces. A promising technique now being studied is the use of rolled panels of porous metal sheet on the leading edges of the flaps through which is sucked in a controlled amount of air.

Since ambient pressure varies across both the length and width of the wing, porous stainless steel sheet having controlled variations in permeability in both directions has been developed to compensate for ambient pressure differences and thus cut power requirements to a minimum. Such a material is made by varying the amount of powder deposited in different areas of the sheet, sintering, coining the resulting sheet to a uniform thickness (thereby varying its density), and annealing. A water-repellent silicone resin coating is baked on to make performance less dependent on the moisture content of the air.

Micro Metallic now makes a standard 0.050-in. stainless steel sheet in which flow capacity can be varied from 3 to 480 cfm per sq ft, based on a pressure differential of 30 lb per sq ft (0.21 psi). This material, designated BLC-1, has a minimum tensile strength of 15,000 psi and a modulus of elasticity of about 7 x 10^6 psi. Other such media having tensile strengths up to 34,000 psi and moduli up to 14 x 10^6 psi have been developed.

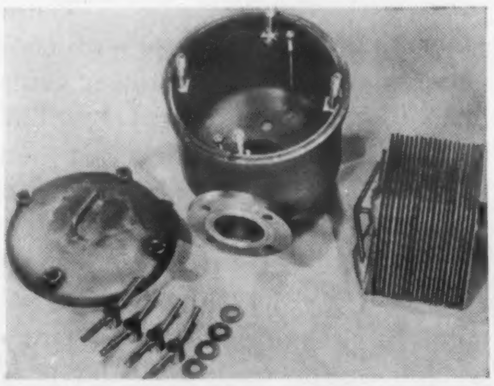
Transpiration cooling of combustion chambers. Now that the high-temperature limits of most engineering materials seem to have been reached, various methods of more efficient cooling are being investigated, particularly for aircraft power plants. One promising method is transpiration cooling, in which a "cool" (i.e., cooler than the gas in the combustion chamber) gas or liquid is passed through the wall to be cooled. The rate of heat transfer through such a boundary layer is quite low, and the transpiration technique requires only a fraction of the coolant needed for external cooling of a solid wall. Porous metal sheet of stainless steel, Haynes Alloy-25 and other heat-resistant materials are being tested for such applications.

Combustion chamber liner *(experimental) made of "Rigimesh" to allow transpiration cooling.*



Just recently, Micro Metallic announced a new porous material developed especially for transpiration cooling. The sheet is made from woven wire cloth instead of metal powders. First, the warp and woof strands of the wire cloth are welded together at all junctions by passing the cloth (in one or more layers) through the sintering furnaces. The rigid cloth is then calendered to reduce pore size, and finally annealed.

The resulting material, called "Rigimesh", is available in standard pore sizes from 0.002 to 0.018 in. and standard thicknesses from 0.005 to 0.050 in. Thickness tolerance is ±0.002 in. Standard material is Type 316 stainless, although N-155 alloy has recently become available for after-burner liners. Rigimesh is ductile and easily fabricated. Typical room-temperature properties for an intermediate-permeability grade of stainless steel are: 37,000 psi tensile strength, 24,000 psi yield strength, 15 x 10^6 psi modulus of elasticity and 9% elongation. High-temperature properties exceeding those of solid Type 304 stainless have been obtained with some Rigimesh grades. Materials with directional properties or with varying permeability can also be produced.



Complete filter *unit components with porous metal leaves.*

See also "Stainless Steel Powder Parts," M&M, Mar. 1955, p. 118-20.

Try

Plastics for Strong Nitric Acid Service

Polyethylenes, fluorocarbons, and polyvinylchlorides are a few of the materials already in successful use as tank liners, coatings, O-rings and gaskets.

by E. J. Zeilberger *of E. J. Zeilberger Associates*

■ In recent years the demand for plastics and synthetic elastomeric materials for use with concentrated and fuming nitric acids has increased significantly. The plastics industry has attempted to meet this challenge with an ever-increasing variety of new materials. For nitric acid service, plastics have been used as liner materials, gaskets, O-rings and other seals, filters and protective coatings.

As a general rule the ethylene family of plastics is the most resistant to nitric acid. Well-known materials as polyethylene, Teflon, Kel-F, Fluorothene, Hypalon, polyvinylchloride, and Saran are in wide use.

Tank liners

Tank liners are an important application for nitric acid-resistant plastic. Most common metals, with the exception of some of the 300- and 400-series stainless steels and several of the aluminum alloys, are severely attacked by concentrated and fuming nitric acids. Aluminum is attacked if the acid is diluted.

There are many good reasons for the use of plastics liners: 1) A plastics liner permits the use of less costly and more available metals for nitric acid tank structure. 2) Plastics liners make possible the use of lightweight structural plastics vessels, an important factor in the aircraft and missile industry. 3) Plastics liners retard sludge and crystal formation in stainless or aluminum vessels.

To date three plastics materials resistant to nitric acid have been utilized for liners: polyethylene and the fluorocarbons, Teflon and Kel-F (Fluorothene). The three materials vary in their resistance to concentrated and fuming nitric acids. Polyethylene is suitable for handling and storage of strong nitric acids for short periods of time, after which the resin is attacked and fails. A recently developed material, irradiated polyethylene, has a higher melting temperature and tensile strength than the regular product, which is achieved through crosslinking the polymer by exposure to radiation. It is probable that the irradiated polyethylene also has improved nitric acid resistance.

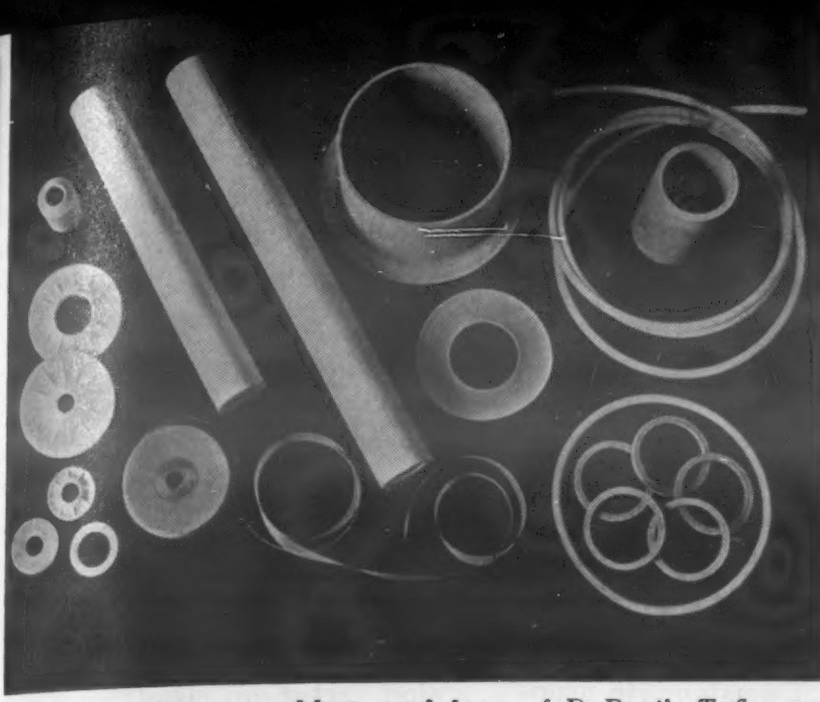
The fluorocarbon plastics are not attacked by nitric acid of any concentration. However, after some time in fuming acids, these materials become somewhat permeable to acid and oxide vapor and lose some of their usefulness as liner materials. Permeability rates should be taken only as relative ratings rather than absolute values, since permeability is often as much a function of the processing of a material as it is an inherent function of the material itself.

Fabrication

Proper design and carefully developed application techniques are essential in fabricating nitric acid liners. Heat sealing and dielectric sealing are standard techniques with polyethylene. The fabrication of Teflon and Kel-F liners is somewhat more difficult. There is no adhesive resistant to nitric acid that will bond these films to themselves or to metal. Special heat and dielectric sealing methods must be used. Kel-F can be successfully bonded to itself by the use of high frequency dielectric sealers, but Teflon cannot be sealed by this method due to its low dielectric loss factor. Heat sealing has proved adaptable for Teflon. Extruded Teflon film is available only in 6-in. widths and shaved film only in 12-in. widths; so large liners require many seams. A material called "non-directional" Teflon film made by the Minnesota Mining & Mfg. Co. is particularly suited for liners, as it has a tear strength superior to any other Teflon film by several orders of magnitude. It also has equal strength in all directions, unlike other extruded Teflon films which have maximum strength in one direction only.

Unplasticized Kel-F liners sometimes present fabrication

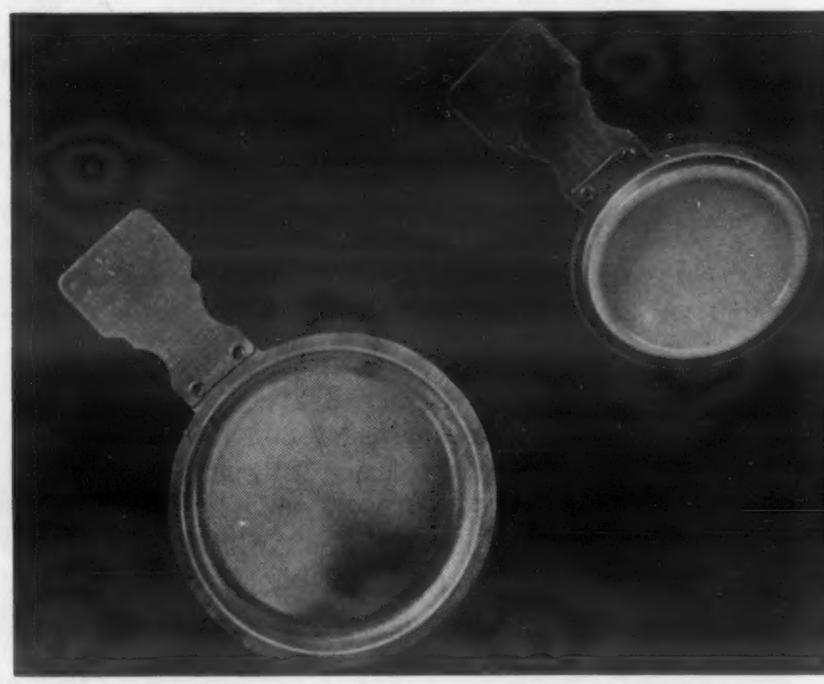
. . . they worked here



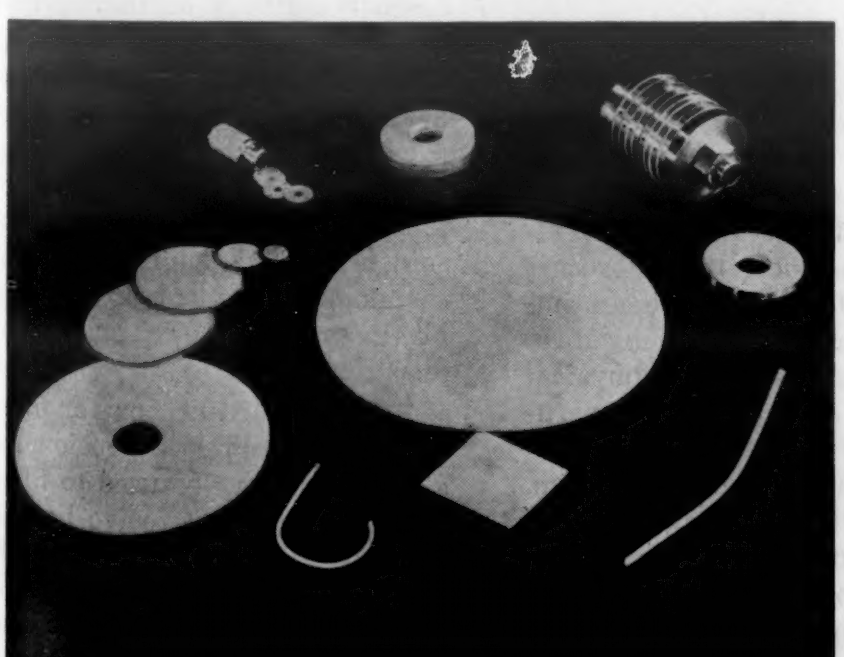
Gaskets, tubing, packing, and tape *of DuPont's Teflon are highly resistant to nitric acid.*

Pressure transducer *used with fuming nitric acid, hydrogen peroxide, and other highly corrosive chemicals, has Kel-F pressure diaphragm. Unit operates at pressures to 3000 psi.*

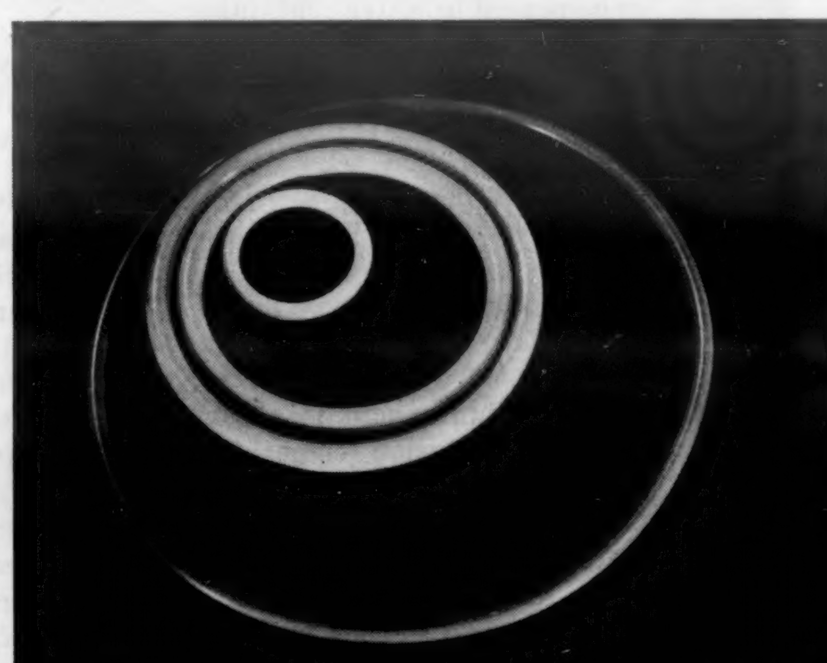
Burette valves *of DuPont's Teflon need no lubricant, are well-suited for nitric acid exposure.*



Burst diaphragms *of aluminum are sensitive to corrosion attack. A thin film of Kel-F resin protects the base metal, maintains proper burst rating.*



Nitric acid filter *at upper right of porous Kel-F polymer is used in rocket fuel lines. Other forms are used to filter fuming nitric acid.*



Resilient core O-rings *compression molded of Kel-F with a silicone rubber core provide wide temperature latitudes without sacrificing resiliency.*

problems due to the "three cornered fold." This fold occurs when the material is bent improperly. With proper liner design the problem can be eliminated.

A plastics glass fiber sheet with a Kel-F film on one surface is a recent development. The reinforced plastics offer structural strength and the inside Kel-F facing renders the tank nitric-acid resistant. The seams of this unit are protected from action of the acid by strips of Kel-F sheet, heat welded to the Kel-F facing.

Plastics coatings

Plastics coatings for nitric acid protection fall into two classes; 1) those which render only splash and fume protection against accidental spillage or protection for vessels having only intermittent service, and 2) coatings which supply protection for long-term service.

Several phenolic coatings and modified epoxy-phenolic coatings give ample splash protection. Such coatings generally require baking temperatures of 300-400 F. A fluorinated coating designated Exon 400XR61 gives superior splash protection against nitric acid and has the added advantage that it can be air cured.

Coatings for long-term service are Teflon dispersion, Kel-F suspensoid, and Kel-F elastomer. Teflon dispersion, a colloidal Teflon dispersed in water containing a wetting agent, requires a Teflon primer having the same composition as the dispersion with phosphoric or chromic acids added. Both coating and primer require a fusion bake at a temperature of 680-720 F.

Kel-F suspensoids need no primer, but for better adhesion the activation of the metal surface with phosphoric acid is recommended. The fusion temperature of the suspensoid is 420-440 F. A coating thickness of about 0.010 in. is recommended with either Kel-F or Teflon coatings in order to insure good acid protection.

Coatings based on a solution of the new Kel-F elastomer in selected solvents will shortly become available. The elastomeric coating is air cured and is said to have acid resistance approximating that of Kel-F suspensoid.

O-rings

In one type of O-ring, the material must be stretched, requiring an elastomeric material. Certain plasticized vinylchloride O-rings can serve for short periods of time. Hypalon O-rings are somewhat better as far as acid resistance is concerned and have excellent elastomeric properties. The recently developed Kel-F elastomer appears to be the best answer to this problem, judging from preliminary tests. Its elastomeric properties are good and its nitric acid resistance appears superior to that of any other elastomer.

O-ring compression seals do not have to be so elastic. Fluorocarbons are excellent only when sealing against moderate pressures. At low pressures they are not sufficiently elastic, while at extremely high pressures they suffer from cold-flow. To reduce the difficulties faced in poor elasticity, cold flow and compression set, and yet retain the good acid resistance of the fluorocarbons, several fabricators have made silicone rubber O-rings with a thin covering (0.005-0.020 in.) of Teflon or Kel-F.

Teflon is now in use for back-up rings for O-rings. Most back-up rings are made of natural leather, which will not stand up against such highly corrosive fluids as nitric acid.

Gaskets

In gaskets for all types of nitric acid service, the fluorocarbons and Hypalon have an important place. Their chemical resistance and superior physical properties over a wide temperature range make them a valuable asset to any nitric acid system. An inert filler such as glass reduces cold flow properties in high pressure applications.

The chevron-type seal for valve stems made of fluorocarbons has replaced other types of stem packing materials, resulting in improved sealing and increased service life. Similar plastics parts for nitric acid valves and pumps are fluorocarbon lip-seals, poppets and valve seats.

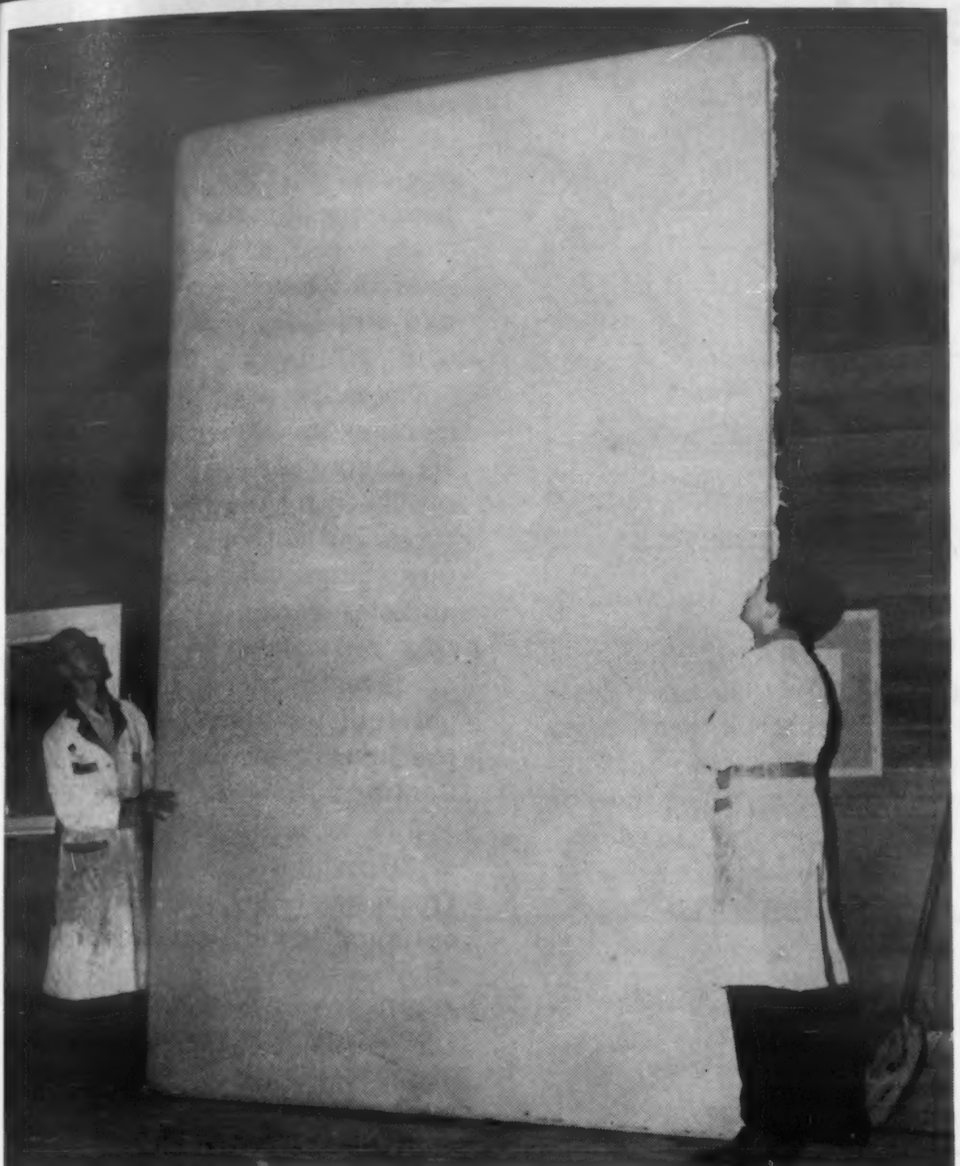
Other parts

Bellows are sometimes employed in systems using nitric acid. Metal bellows used up to now have two shortcomings: stainless steel or aluminum welded bellows often fail due to a combination of preferential weld attack and metal fatigue; and the expansion factor of metal bellows is too low for some applications. Bellows made from an elastomer can often meet the mechanical requirements better than metal, but common elastomers have poor nitric acid resistance. The new Kel-F elastomer seems to possess all the properties needed in bellows for service with nitric acid.

Bearings for flowmeters and other rotating members of instruments for nitric acid demonstrate fluorocarbon versatility. Teflon bearings, either in the pure form or with such lubrication fillers as graphite or molybdenum disulfide, give excellent service.

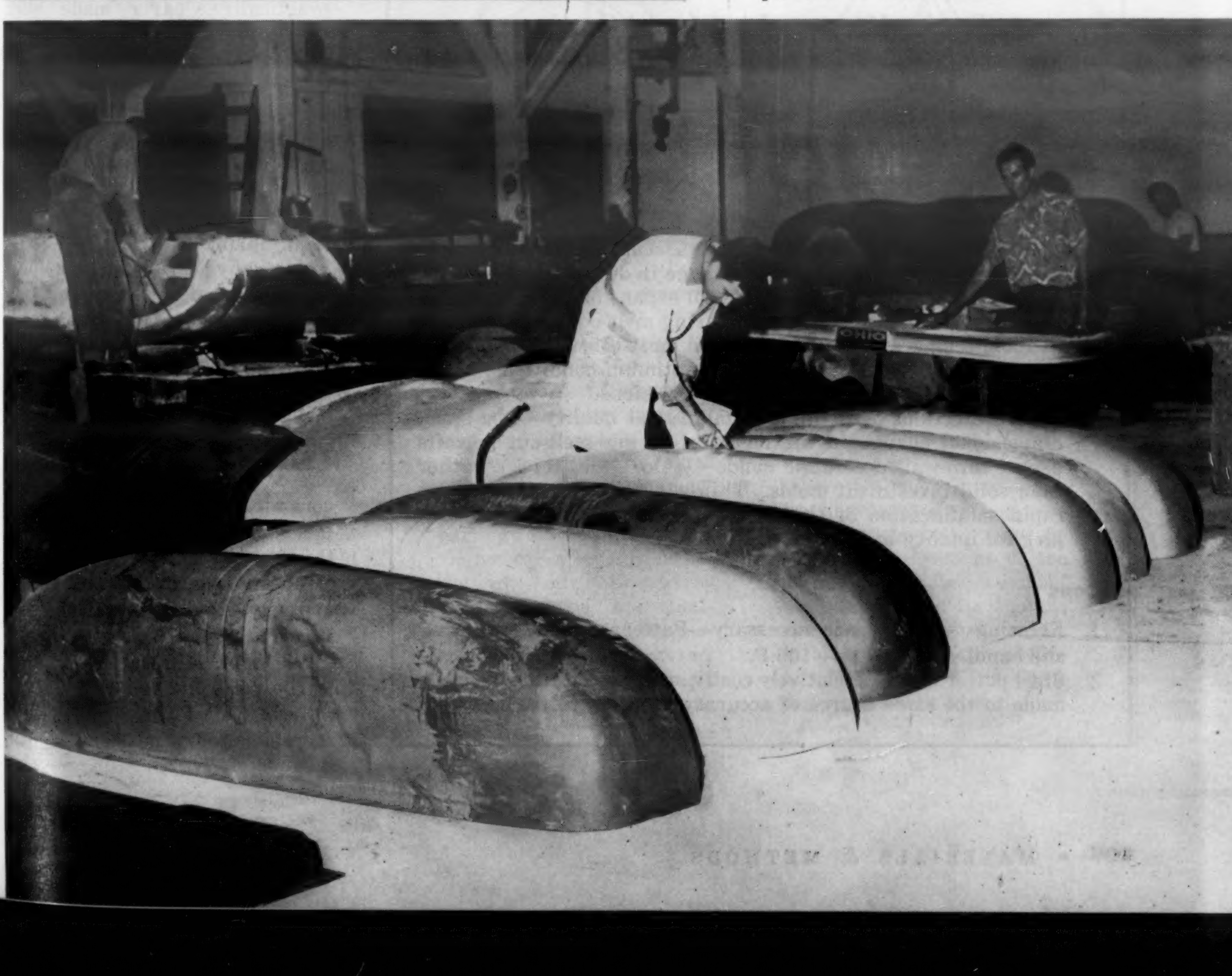
Burst diaphragms in pressure vessels must burst at a pressure lower than the burst pressure of the vessel but above the working range of the system. Such diaphragms must be protected from corrosive attack of the fluid in the vessel, since even a slight change in the diaphragm thickness radically changes the burst pressure. Aluminum bursting disks can be coated with a thin film of Kel-F. The Kel-F suspensoid is applied prior to forming the dome. Low porosity of the plastic prevents attack on the diaphragm metal.

Porous fluorocarbons for filter service are highly corrosion resistant and may be used to filter or vent highly corrosive liquids and gases under pressure. Kel-F applications include aircraft oil filters and rocket nitric acid line filters. Stock and disk forms, as well as porous rod or "wick", are in use for filtering fuming nitric acids.



Topping Trucks With Plastics

Fresh from the mold, this 8-x 12-ft truck roof is translucent, allowing natural light in truck interiors. Bows are molded integrally into the roof, minimizing possibilities of breakage. Molded by Clearfield Plastics, Inc., with Reichold Chemicals' Polylite polyester resin and glass cloth reinforcing, the roof weighs only 93 lb or 1/3 to 1/5 the weight of a steel roof. At bottom workmen are putting finishing touches to plastics truck roof caps, which may be used in conjunction with either plastics or metal roofs.



Large, Intricate Shapes Made by Investment Casting

Frozen mercury technique makes possible castings weighing 80 to 100 lb and having dimensions in excess of 36 in.

by **Irvin R. Kramer,** *Vice President, Mercast Corp.,* *and* **Davidlee Von Ludwig,** *Consultant*

Frozen Mercury Investment Casting

Pros

1. Large size castings—Low volumetric shrinkage of mercury and its dimensional stability when frozen permits larger accurate castings than are commercially practical with wax or plastics patterns. Size of castings is limited only by facilities of foundry.
2. High accuracy in complex castings—The unique booking properties of frozen mercury permit the assembling of highly complex patterns with virtually no change in dimension across the parting line. Mercury's low thermal expansion results in relatively little dimensional change during melt-out of the pattern at room temperature. Tolerances on most dimensions of parts can be held to ± 0.003 in. Under optimum conditions, closer tolerances can be held on critical dimensions.
3. Thicker sections with high metallurgical quality—The small dimensional change in the mercury during melt-out permits use of thin-walled ceramic molds (1/8 to 1/4 in. thick), rather than solid investment molds. Thin-walled molds permit more rapid solidification of the molten metal and improved metallurgical quality in heavier sections of castings.

Cons

1. Freezing facilities are necessary—Patterns must be frozen and handled at —70 to —100 F.
2. Steel pattern dies—Relatively costly steel pattern dies must be made to the same degree of accuracy required in the castings.

■ The use of frozen mercury patterns frees investment casting from many of the size and thickness limitations imposed by wax or plastics patterns. Castings made by wax or plastics pattern techniques rarely weigh more than a pound, section thickness does not often exceed 0.250 in., and dimensions seldom approach 6 in. in any one plane.

The major application of frozen mercury investment casting is not for shapes competitive with those produced by wax or plastics patterns, but rather for larger, complex shapes with heavier sections and closer over-all tolerances. In this respect, it is an extension of investment casting, and its possibilities open new fields for the investment casting industry. Castings weighing from 80 to 100 lb, with dimensions in excess of 36 in., have been cast by the frozen mercury process. Under optimum conditions of design, alloy and foundry control, critical details can be held to closer than the ± 0.003-in. tolerance commonly encountered with frozen mercury patterns.

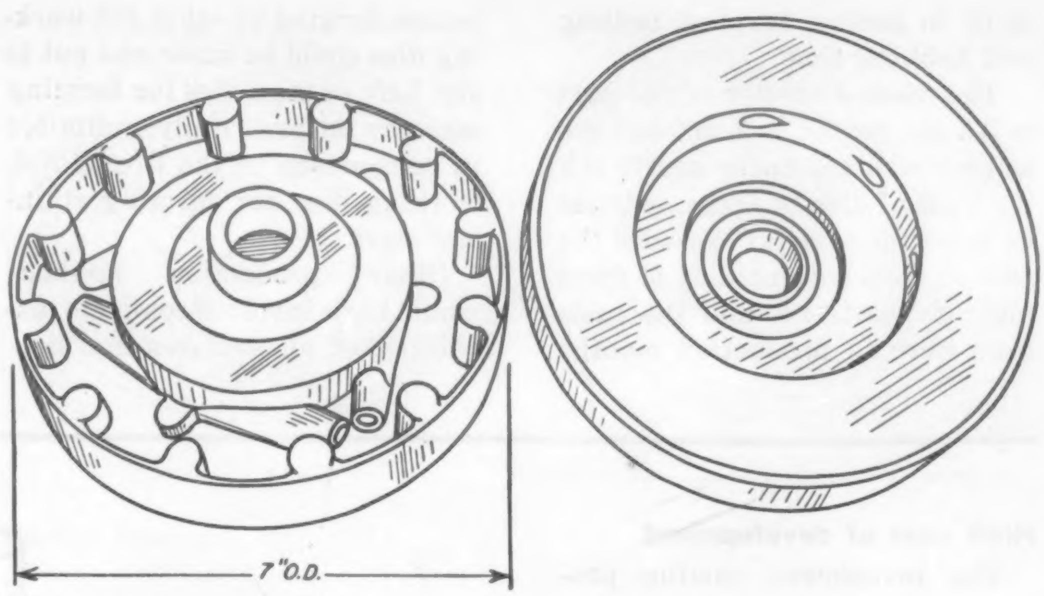
Within limits of commercial practicality, parts made with mercury patterns have the following advantages over those made with other disposable materials: 1) smoother and more accurate; 2) greater internal cored detail; 3) thinner sections over greater areas free from defects; 4) thicker sections free from shrink. In addition to inherent physical and dimensional advantages of mercury, its liquefaction during melt-out takes place with so little thermal stress and dimensional change that thin ceramic molds may be used instead of solid investment molds. The mold is applied by dipping in one or more slurries of a special ceramic formula. The resulting inert shell is about 1/8 to 1/4 in. thick, and sets with sufficient strength to permit melting of the mercury core at room temperature. The mold is fired at 1800 F for 2 hr prior to casting.

The parts to be discussed here, all relatively large, are good for frozen mercury pattern method.

Difficult shape to machine

The aircraft fuel pump casting shown is cast in 356-T6 aluminum alloy, a readily machinable metal. The over-all size of 7 in. and the section thicknesses of from 0.125 to 0.450 in. would tend to favor sand or permanent mold casting methods. However, the three pairs of venturi-curved fluid metering jets located on accurate 120-deg centers around the central housing comprise an important detail, difficult to machine. It would be costly and impractical to machine the six curves with uniformly smooth, balanced curves, accurately centered. The problem is compounded by difficulty in gaining access to the passages for machining.

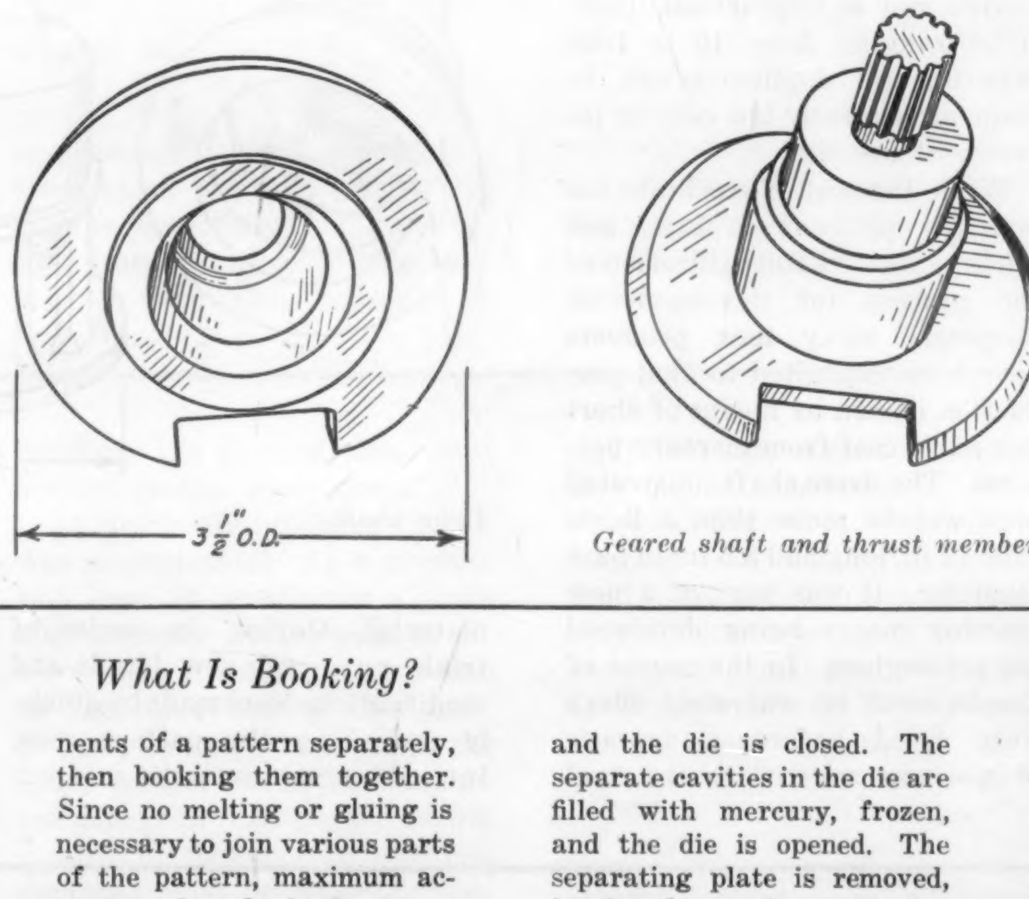
The venturi passages are formed with highly accurate matched steel cores in the mercury pattern. Accuracy of location is such that the passages are used in the as-cast condition and serve as location or reference points for machining other final details. Metallurgical specifications, such as freedom from porosity and other defects, are satisfactorily met with the investment casting.



Aircraft fuel pump

High scrap loss

Changing from machining a part from bar stock to investment casting can result in substantial reductions in scrap loss. The splined or geared shaft and thrust member used in a new type of radar for guided missile control illustrates this. It had to be made of an austenitic stainless steel for strength, corrosion resistance and magnetic properties. Machining the part from solid bar stock involved a scrap loss of 80% of bar stock volume and a high invest-



Geared shaft and thrust member

What Is Booking?

Booking is the term applied to the process of joining two or more pieces of frozen mercury by merely holding them together. Frozen mercury has the unique property of welding to itself and producing, in effect, a fusion weld. The weld can be obtained with only slight hand-pressure. The importance of booking lies in the highly complex shapes and cores which can be produced by freezing several components of a pattern separately, then booking them together. Since no melting or gluing is necessary to join various parts of the pattern, maximum accuracy is obtained across "parting lines".

Draw cores, usually necessary with other investment casting methods, are eliminated by introducing a separating plate in the pattern die. Core details are placed on alternate surfaces of the plate and the die is closed. The separate cavities in the die are filled with mercury, frozen, and the die is opened. The separating plate is removed, leaving the cored passages impressed in the frozen mercury. The exterior sections of the die are then replaced without the separating plate and the mercury welds, forming an accurately alligned pattern within which flash-free cored passages have been formed.

ment in boring, turning, milling and hobbing time.

The mean diameter of the part is 3.5 in., height is 5 in., and the as-cast wall thickness nearly 0.5 in. Cost of dies to forge, extrude or upset the part far exceeded the cost of steel pattern dies to form mercury patterns, and the castings were in production months before forging or other hot working dies could be made and put to use. Life of steel dies for forming mercury is practically unlimited in comparison to the life of hot-working dies for forming stainless steel.

Other production methods would have involved complete machining of all surfaces and hobbing the spline. The teeth of the cast gears were used as-cast with only the usual foundry clean-up or buffing to remove incidental surface irregularities. Some final lathe operations complete bearing and reference surfaces, with a conversion to scrap waste of less than 10% of the as-cast metal weight.

High cost of development

The investment casting processes afford a relatively low cost way of producing prototype and semi-production models with properties and characteristics similar to those required of the final production part. Also, since any castable alloy can be formed by investment casting, extreme flexibility exists in evaluating different metals and alloys. Where machining more than a few test models may be impractical, quantities ranging from 10 to 1000 experimental duplicates can be made at relatively low cost by investment casting.

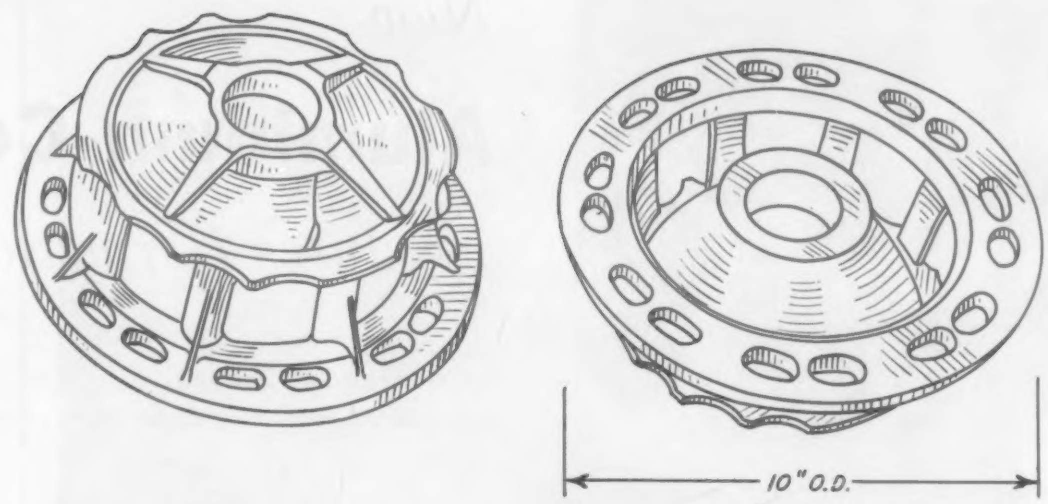
While the cost of steel dies for mercury patterns is high and tends to restrict full utilization of the process for developmental purposes, many new products have been expedited to final production design by means of short run parts cast from mercury patterns. The drive shaft illustrated here weighs more than 3 lb, is over 12 in. long and 3.5 in. in base diameter. It was part of a new starting motor being developed for jet engines. In the course of development several steel alloys were tried before manganese bronze was selected as the final material. During the series of trials, numerous new details and modifications were made by quickly reworking the pattern dies. Internal contours, webs and external clutch teeth were used as-cast and foundry finished. Only bearing and reference or thrust surfaces were finished by machining.

Drive shaft

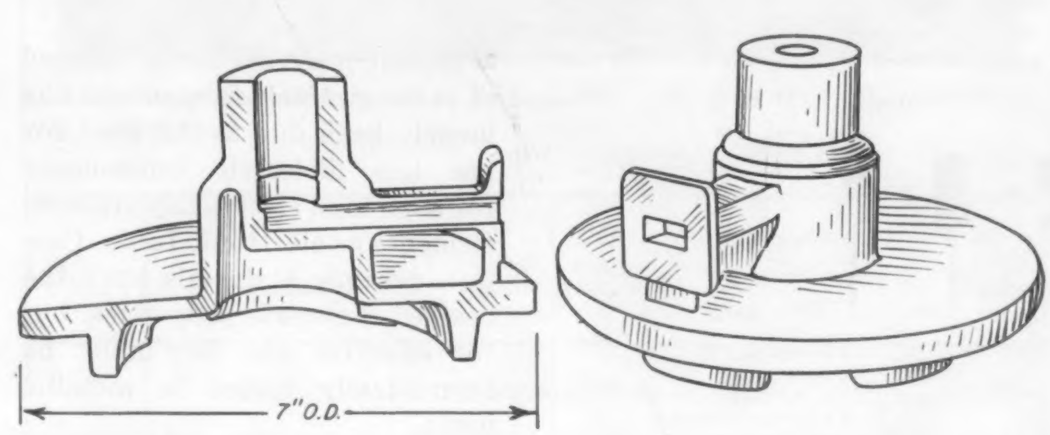
Costly machining and joining

Use of frozen mercury patterns permits substitution of a unit casting for comparatively large weldments such as the 5-lb, 9-in. dia burner housing for an aircraft engine heater unit. Original design called for an assembly made by welding more than 12 components, each of which had to be machined from heavy plate. The SAE 4630 alloy was difficult to machine and even more difficult to weld. Alignment between planes, concentricity and over-all dimensional tolerances were difficult to hold during assembly. Final parts were not satisfactory in service.

The casting which replaced the weldment was lighter, stronger, smoother and substantially more accurate. Air ports, center support struts and flow surfaces



Burner housing



Wave guide

were all smoother and more adequately contoured in the as-cast condition, creating less turbulence and less resistance to secondary air flow into the burner housing. Three facing operations complete the casting for assembly.

Many parts for radar gear were originally designed as asssemblies. Often these designs proved not only costly to produce, but undependable in electronics characteristics, resulting in high reject rates. Unusual electrical and mechanical requirements in some new guided missile tracking devices neccessitated the use of beryllium copper to obtain the proper combination of strength and electrical conductivity. Typical of one of the parts produced from mercury patterns is the beryllium copper wave guide casting also shown here. These pieces weigh from 3 to 6 lb as-cast, and have diameters from 5 to 8 in. with sections varying from less than 0.125 to more than 0.5 in. The channels must be smooth, free from any surface irregularities, pits, hairlines or cracks.

The booking die technique possible with frozen mercury permits the production of intricate wave guide channels in patterns and castings without surface interruptions normally caused by parting lines. Parting lines result from draw cores normally used to form such passages in other types of patterns. Booking dies allow cored passages to be formed with mismatch of less than 0.003 in. in the 0.9 x 0.4-in. rectangular cavities.

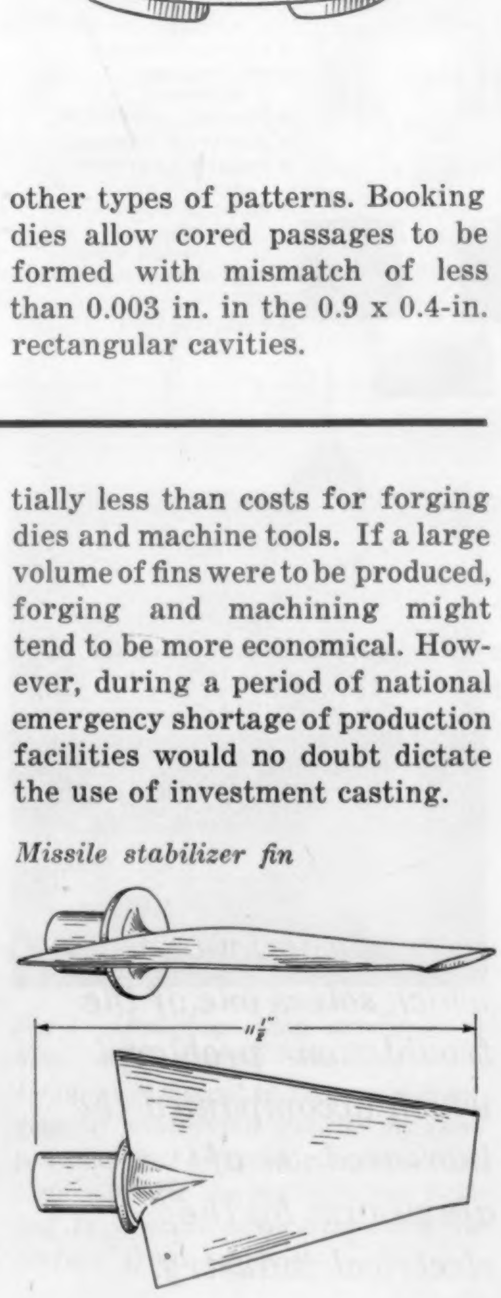
Alternate emergency method

Tools which may be readily accessible during "normal" times may be inaccessible in periods of national emergency. Therefore, when production methods are being evaluated, it is essential to consider alternate techniques for abnormal production conditions. The SAE 4130 steel guided missile stabilizer fin would normally be produced as a hot forging and finished by contour milling to produce the required airfoil sections. Forges large enough to handle the 11.5-in. long, 8-in. wide area of steel with extreme section differences between the 2-in. hub and the tapered fin sections which trail to edges of 0.050-in. radius are not common even in normal times. Contour mills capable of handling the part in alloy steel are not routine equipment.

As originally produced the fin was experimental. As a production item, it constitutes a probable headache. All details of design make it difficult to produce by forging or casting. The tapered airfoil section fastened to the heavy control hub imposes severe metallurgical stresses during casting or forging. In addition, surfaces must be smoothly contoured, free from pits, cracks or lines.

Quantity of parts is often the final detail which determines the most economical production method. For limited production quantities, tooling costs for pattern dies to produce mercury patterns for casting the fin are substantially less than costs for forging dies and machine tools. If a large volume of fins were to be produced, forging and machining might tend to be more economical. However, during a period of national emergency shortage of production facilities would no doubt dictate the use of investment casting.

Missile stabilizer fin



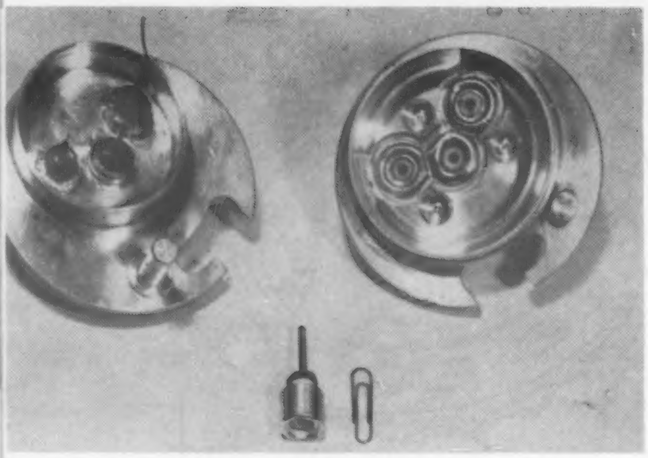


Fig 1—Header, next to paper clip, is composed of 42% nickel-iron cap and aluminum bushing hermetically sealed to alumina ceramic insulator. Two views are shown of final assembly with three headers in place.

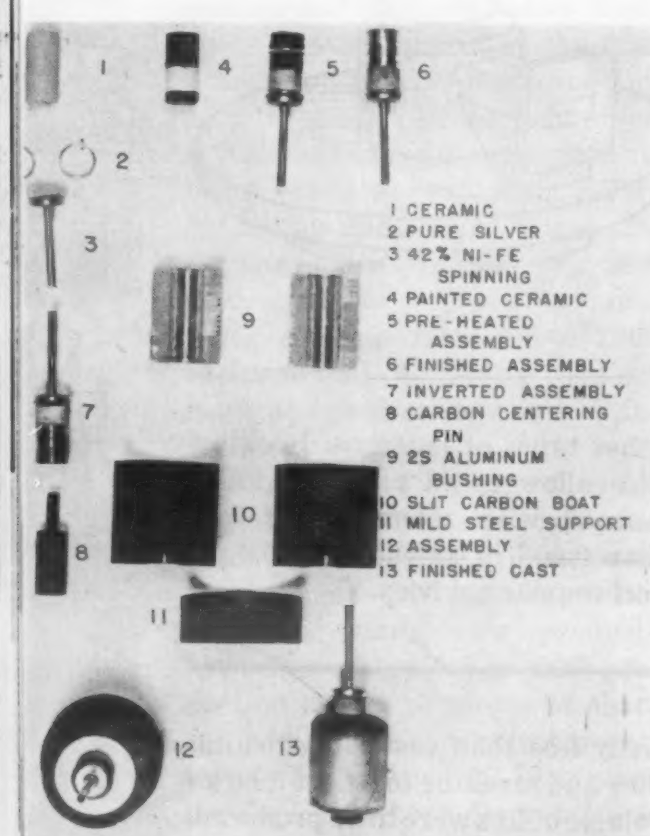


Fig 2—Various elements of header indicate procedure for assembling.

New

Aluminum-Ceramic Bond

Produces Hermetic Seal

by George W. Hume,
General Engineering Laboratory, General Electric Co.

Here is a technique which solves one of the troublesome problems which accompanied the increased use of aluminum by the electrical industry.

■ Recent progress in the science of joining metals to ceramics has largely been due to the need for low loss dielectric components for such high electrically stressed elements as electronic tubes. Certain ceramic materials have the desired dielectric properties, but for effective use they must be hermetically sealed to metallic parts.

There are many methods of sealing non-conductors to metals, some of the more commonly used being fernico-glass seals, silver paste, platinum paint, molybdenum-manganese and molybdic oxide. Selection of a method is generally governed by the specific application. None of these methods, however, is used to form high temperature hermetic seals with aluminum and its alloys. With increasing use of aluminum in the electrical industry, the problem of joining aluminum to other metals and to non-conductors such as ceramics has become a major one.

G-E has found that by modifying a joining method developed in their Research Laboratory for other metals, a satisfactory high temperature hermetic seal can be obtained between ceramic materials and aluminum and its alloys. The basic process involves the use of either titanum or zirconium hydride to coat the ceramic surface with elemental titanium or zirconium to which filler materials can alloy and bond the metallic component. It is used in the laboratory because it is versatile and can be used with either soft solder or high temperature brazing alloys. In general, zirconium hydride can be used wherever titanium hydride can be used, to solder ceramics and other materials such as Pyrex, quartz and carbon.

The modification of the process for the purpose of joining aluminum can best be illustrated by describing one application. It consists of fabricating the header shown in Fig 1 which is used in a 1100 aluminum alloy ionization chamber. Specifications call for insulating and hermetically sealing three electrical leads extending through the header. The headers are successfully sealed by using either zirconium or titanium hydride as a means of metallizing the alumina ceramic surface with a solder and subsequently alloying aluminum to the metallized area.

Technique

The first step is the tinning operation. Though zirconium hydride is used in this case, titanium hydride provides an equivalent bond. Zirconium hydride powder is painted on the ceramic from a liquid suspension. After the liquid has evaporated, leaving a film of zirconium hydride about 1 mil thick (step 4, Fig 2) a ring or washer of a solder such as pure silver is placed around the painted area (step 5, Fig 2). The assembly is then placed inside a tantalum heat shield and a bell jar is used to apply a vacuum of

one micron or less while the entire assembly is heated by induction coils. The zirconium hydride breaks down at around 900 F leaving elemental zirconium on the ceramic surface while nascent hydrogen is pumped out of the vacuum system. As heating is continued the silver melts, wetting and alloying with the zirconium. Heating cycle requires 8 to 10 min reaching a maximum temperature of about 2000 F. Cooling under vacuum requires about ½ hr. It will be noted that in this case a 42% nickel-iron cap was simultaneously soldered to the ceramic during the tinning operation (step 6, Fig 2).

The second step, that of casting and alloying aluminum to the tinned area was accomplished by placing the tinned ceramic in a 1100 aluminum alloy bushing (step 9, Fig 2), centering the assembly in a carbon boat and again applying a vacuum in a bell jar. Upon heating, the aluminum bushing melts and alloys with the tinned area of the ceramic, producing a sound dendritic structure. The resulting assembly is shown in step 13, Fig 2. The bushing can then be joined to the header by brazing or inert arc welding.

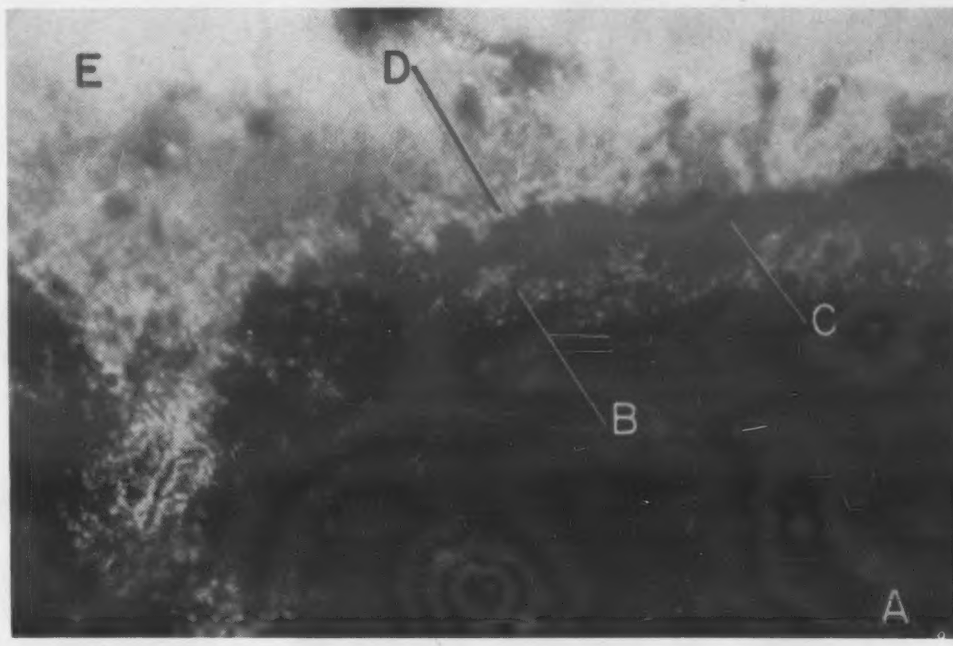
Bushings are leak tested on the G-E mass spectrometer (Type M) leak detector. Testing consists essentially of detecting leaks under reduced pressure on the internal portion of the bushing. Helium is dispersed over the outside of the bushing by means of a probe. If any helium leaks through the ceramic, aluminum-to-ceramic seal or through the aluminum itself, the ion gage indicates the rate at which helium is entering the system. In this application any indication of leakage requires rejection of bushing. Experience to date indicates a 2% loss due to leakage.

Bushings are electrically tested for a total resistance of at least 10^{12} ohms between the aluminum and the 42% nickel-iron cap at room temperature. Since dirty ceramic material will not pass this test, a light sand blast may be necessary to remove foreign material from the ceramic portion of the header.

The headers have also passed the Navy high impact shock test, MIL-S-901, as well as the vibration test, 40-T-9 (ships). Samples tested for tensile strength averaged 5840 psi. Others tested in a humidity chamber at 100 F and 100% relative humidity for 1000 hr showed no visible corrosion. Samples tested in a 5% salt spray chamber for 500 hr showed slight corrosion on the aluminum, though they subsequently passed leak testing.

Acknowledgment

The author wishes to acknowledge the assistance of F. C. Kelley and R. Bondley, who developed the titanium or zirconium hydride sealing method in the G-E Research Laboratory.



Aluminum-ceramic bond *characteristics shown in this photomicrograph (400x).*

Area	Section	Thickness (mils)	Diagonal (microns)	Microhardness		Remarks
				VHN	Rc	
A	Ceramic (No apparent indentation under testing conditions used.)					Very hard
B	Ag + Zr (enriched layer)	0.5	23	349	36	Hard[a]
C	Intermetallic layer	0.25	28	236	20	Hard[b]
D	Ag + Zr (enriched Al)	—	73	35	—	Soft
E	Al base	—	80	29	—	Very soft[c]

[a] *Silver-zirconium enriched layer adjacent to ceramic had hardness of tempered steel indicating solid solution hardening of silver and zirconium.*
[b] *Unidentified intermetallic diffusion layer was softer than silver-zirconium enriched layer; comparable in hardness to soft steel.*
[c] *Aluminum base characteristic of completely annealed aluminum. Note hardness of various layers increases from aluminum to ceramic.*

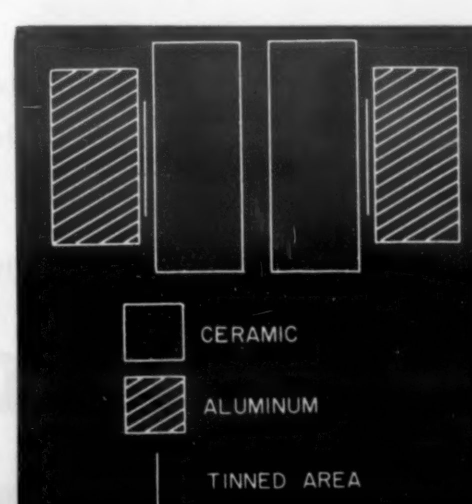


Fig 3—Drawing shows aluminum is also cast around bare ceramic. Higher coefficient of thermal expansion of aluminum results in compression seal between aluminum and bare ceramic during casting, helping to protect silver-aluminum interface from corrosion.

Agitator *shows no corrosion after 3-mo service in zirconium phthalate solution at a temperature of 165 to 190 F. This solution, containing hydrochloric and phthalic acids and traces of ferric and other chlorides, attacks type 316 stainless steel rapidly.* *(Bureau of Mines)*

Chemical and process industries
Electrical and electronics fields
Nuclear power reactors

will be major users of...

Commercial Zirconium

Though still expensive, at about $30 per lb., its outstanding properties make its use feasible for a number of products.

by John L. Everhart, *Associate Editor, Materials & Methods*

■ After several years of development, zirconium is now available in commercial quantities in the form of plate, strip, forgings and wire while tubing can be obtained in small quantities. The price, which ranges from $27 to $35 per lb, although higher than that of similar titanium shapes, is competitive with tantalum at $39 per lb.

The purest and most ductile zirconium is obtained by the decomposition of zirconium iodide; but, in the present stage of development, this procedure is expensive and not well suited to quantity production. Commercial zirconium is therefore produced by the Kroll process, involving the reduction of zirconium tetrachloride with magnesium.

Kroll zirconium is obtained in the form of sponge. To produce massive zirconium suitable for fabrication, the sponge is consolidated by melting under a vacuum or a controlled atmosphere. As can be determined from the table of chemical composition, commercial zirconium is not chemically pure. Actually it is an alloy of hafnium and zirconium containing about 2% hafnium. However, the properties of hafnium and zirconium are so similar that within the normal range of hafnium content, there is practically no change in mechanical properties resulting from its presence.

On the other hand, the mechanical properties of zirconium are quite sensitive to small quantities of several other impurities, particularly oxygen, nitrogen, hydrogen and carbon. Of these, oxygen and nitrogen have the most pronounced effect. The increase in strength resulting from a moderate increase in these elements is shown in a table.

Physical and mechanical properties

Some of the properties of zirconium are given in accompanying tables. Density is intermediate between that of iron and titanium and is about 40% that of tantalum. Since zirconium is

expected to compete with tantalum in corrosion-resisting applications, the lower density is a distinct advantage. The thermal expansion characteristics and the electrical resistivities of zirconium are comparable with those of type 410 stainless steel.

The melting point is about 200 F above that of titanium and about 2000 F below that of tantalum. Melting point is not particularly important, however. Because of their reactivity none of these metals can be used for continuous service in the atmosphere at temperatures much above 700 F, which greatly restricts their high temperature applications.

Annealed zirconium has a tensile strength similar to that of 18:8 stainless steel but the yield strength is considerably higher. Here the comparison ends, for zirconium is harder and much less ductile than the steel.

An accompanying graph shows the effect of cold-working on the mechanical properties of zirconium. Increases in strength through cold-rolling are not so marked as they are with austenitic stainless steels. For example, yield strength of zirconium increases only from 60,000 to 110,000 psi with 50% cold reduction, while under the same conditions, that of 18:8 increases from about 40,000 to 180,000 psi. However, loss in ductility which accompanies the cold-working of zirconium is great enough to limit seriously the total work which can be done between anneals.

PHYSICAL PROPERTIES[1]

Density, lb/cu in.	hot rolled cold rolled	0.237 0.234
Melting Point, F		approx 3325
Thermal Cond Btu/hr/sq ft/ft/°F at 250 F		8.46
Coef Thermal Exp/°F (70-390 F)		3.0×10^{-6}
Specific Heat Btu/lb/°F at 70 F		0.067
Elect Res, Microhm-Cm at 70 F		53–60
Elect Cond, % IACS, 70 F		2.7
Temp Coef of Res/°F (32–212 F)		$14\text{–}16 \times 10^{-4}$
Mod of Elasticity, annealed		$11\text{–}14.8 \times 10^{6}$

[1] *Commercial zirconium containing about 1.5 to 2% hafnium.*

MECHANICAL PROPERTIES OF ZIRCONIUM

Form	Section Size in.	Condition	Ten Str, psi	Yld Str (0.2% offset), psi	Elong, % in 2 in.	Rockwell Hardness	Charpy Impact Strength V-Notch, ft-lb
BAR	1	As hot-rolled	105,000	85,000	10	A61	4
	1	Annealed at 1300 F	88,000	64,000	12	A58	6
STRIP	0.125	Annealed 1 hr at 1400 F[1]	84,000	53,000	10	A54	—
	0.035	Annealed 1 hr at 1400 F[1]	77,000	—	14	A50	—
WIRE	0.060	Cold-drawn	104,000	—	3.7	—	—
	0.060	Annealed 1 hr at 1400 F[2]	78,000	—	19	—	—
	0.015	Cold-drawn	109,000	—	1.0	—	—
	0.015	Annealed 1 hr at 1400 F	80,000	—	12	—	—

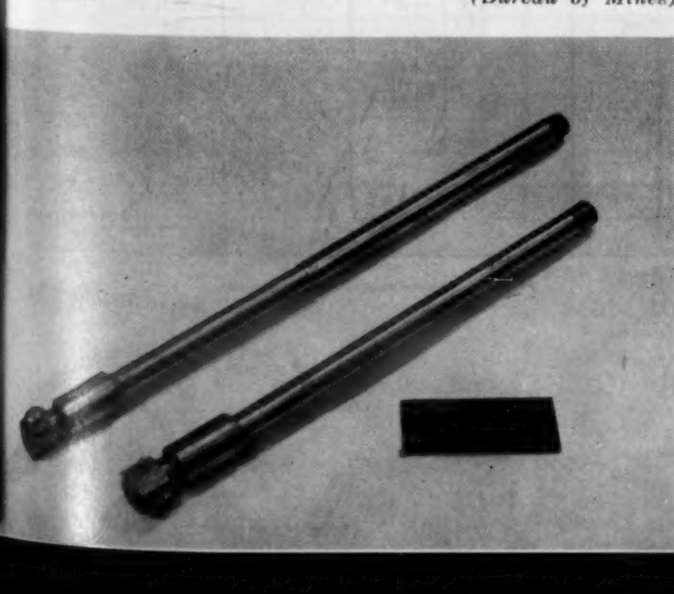
[1] *Annealed in air.*
[2] *Annealed in argon.*

Zirconium loses strength quite rapidly with rising temperature. At 600 F, tensile strength is reduced to 50% of the room temperature value. However, elongation is doubled, and there is about a 15% increase in reduction of area.

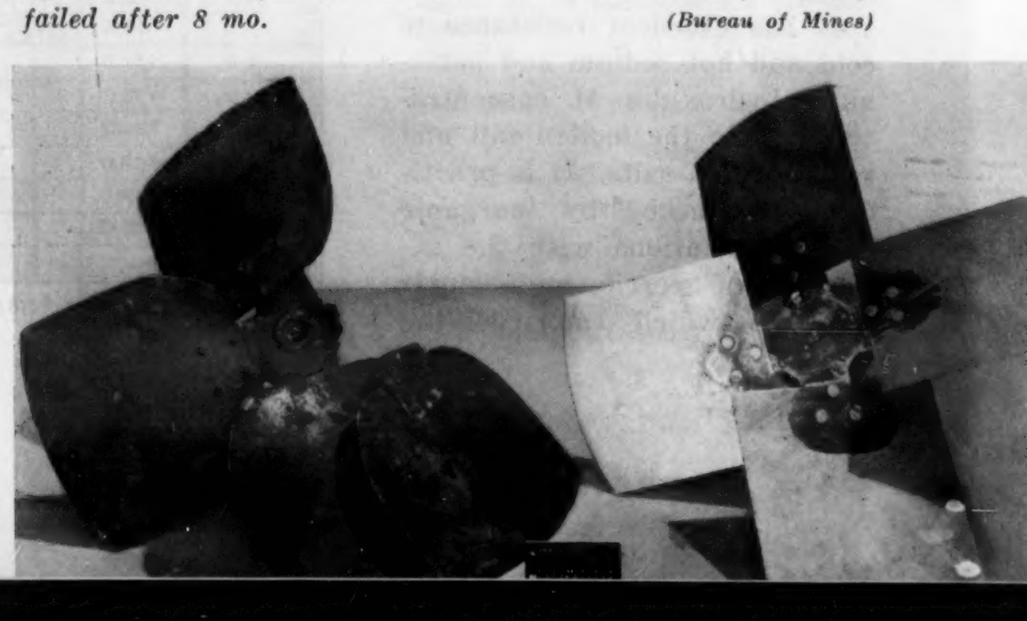
Corrosion resistance

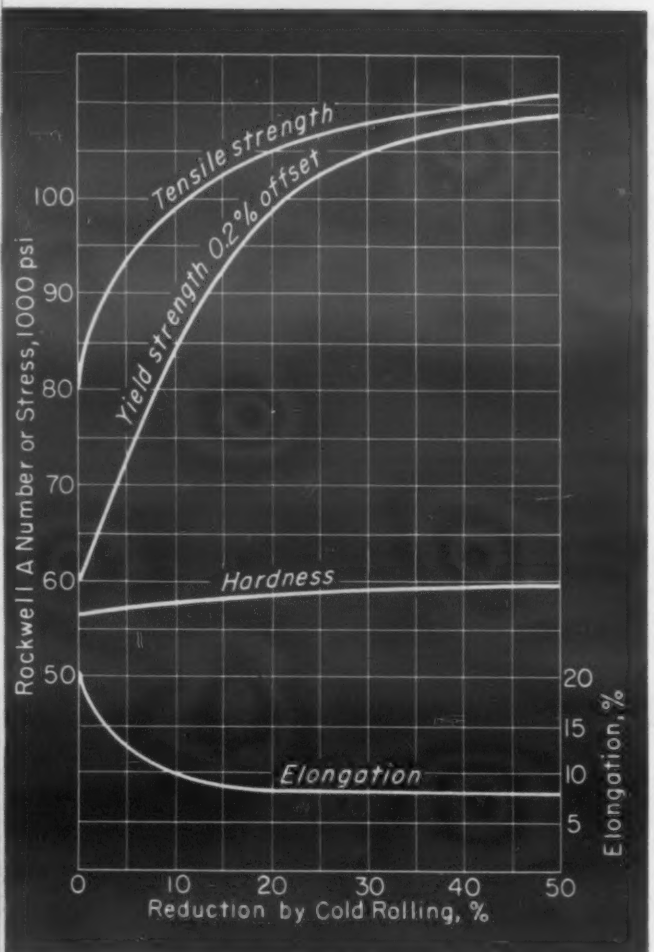
The excellent corrosion resistance of zirconium to many me-

Zirconium spray nozzles, *couplings and pipe (bottom) after 14-mo service in the exit of a chlorine scrubbing tower in contact with wet chlorine and chlorides of hydrogen, iron, aluminum, silicon and titanium. Top pipe is pure nickel after 6-wk service.* *(Bureau of Mines)*



Zirconium exhaust fan *(right) after 10-mo service handling hydrochloric acid fumes. Plastic coated steel exhaust fan (left) failed after 8 mo.* *(Bureau of Mines)*





Effects of cold rolling on the mechanical properties of commercial zirconium.

(Zirconium Metals Corp. of America)

dia is probably the outstanding property of commercial interest. It is practically as resistant to most acids as tantalum and has greater resistance to alkalies.

Zirconium exhibits outstanding resistance to hydrochloric acid in concentrations through 20% and at temperatures through the boiling point.

It shows excellent resistance to nitric acid in all concentrations and to sulfuric acid up to a concentration of 80%. It is also highly resistant to most organic acids. It is attacked by hot concentrated sulfuric, phosphoric and trichloracetic acids and is soluble in hydrofluoric acid.

It has excellent resistance to cold and hot sodium and potassium hydroxides at concentrations up to the molten salt and resists fused salts. It is practically unattacked by inorganic chloride solutions with the exception of ferric and cupric chlorides which embrittle the metal. Unlike tantalum which is highly resistant to the halogens, zirconium is not recommended for use in processes involving chlorine. However, zirconium spray nozzles in actual plant installations, in contact with a mixture of wet chlorine and hydrochloric acid, showed no appreciable corrosion in 5 yr.

Fabrication

Zirconium has a crystal structure similar to that of magnesium. Although metals having this structure are less easily cold-worked than those having a structure like copper or iron, zirconium can be fabricated more easily at room temperature than magnesium. By the use of intermediate anneals, zirconium has been cold-drawn into cups of considerable depth. The metal can also be spun cold. Bending operations, particularly of difficult shapes, can be improved by raising the temperature. For such operations, temperatures in the 400 to 600 F range are satisfactory. (*Fabrication of zirconium will be the subject of a forthcoming article. Ed. note.)*

Applications

For most applications, the presence of hafnium is not detrimental. This is not true for nuclear reactor applications, since hafnium has a high thermal neutron absorption cross-section and must be removed to produce zirconium having suitable characteristics. The nuclear energy field is expected to continue to be the major user of zirconium in the future. Separation of hafnium from zirconium, while unnecessary for uses other than nuclear energy, will eventually be inexpensive, according to one producer. In the future, all zirconium will probably be hafnium-free, and hafnium will become available at a more realistic price.

The principal use of commercial zirconium will probably be in the chemical industries and in other applications where its ex-

TYPICAL COMPOSITION (BALANCE ZIRCONIUM)

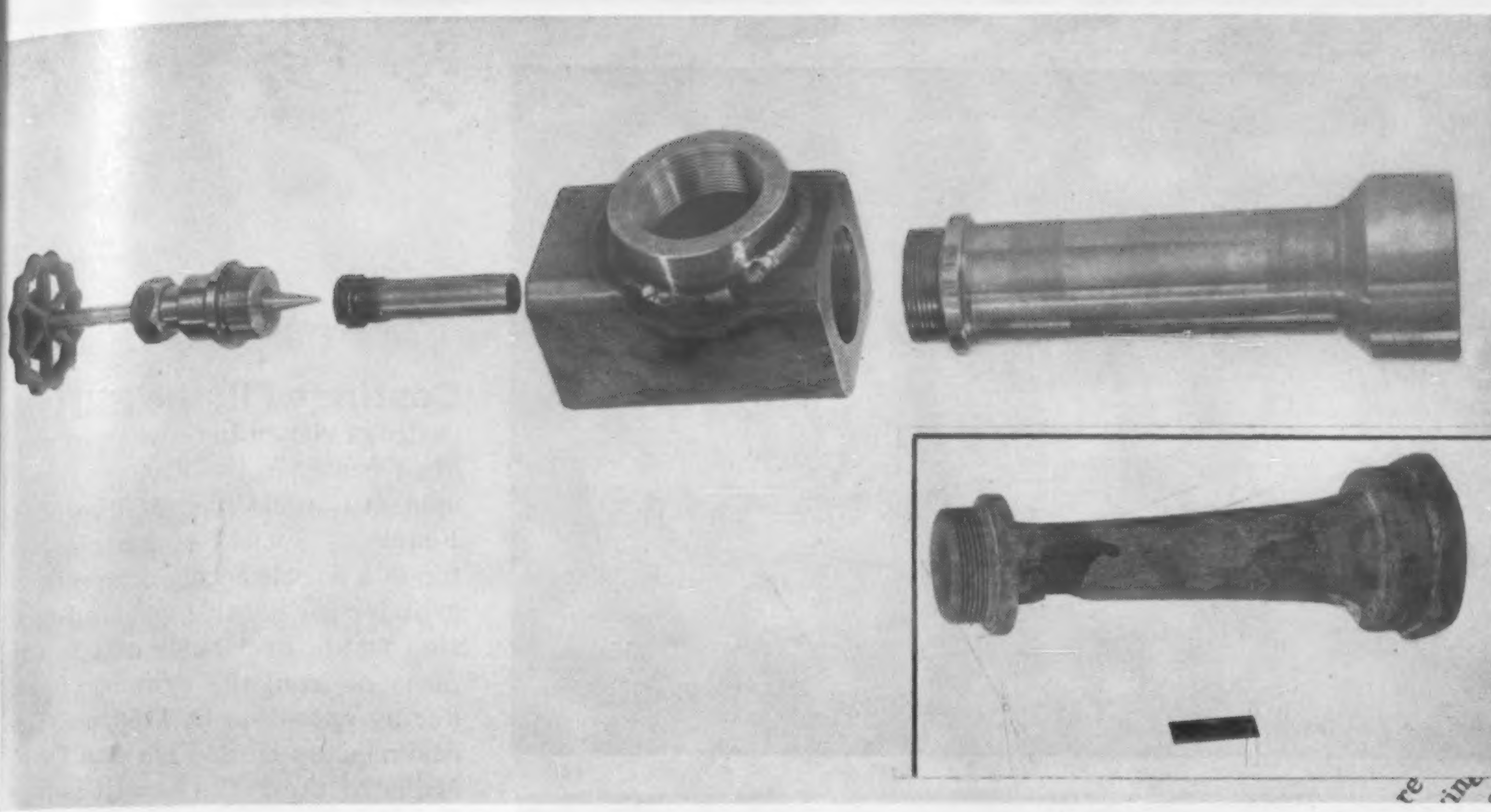
Element	%
Hafnium	1.5-2.5
Oxygen	0.05-0.12
Nitrogen	0.08-0.14
Carbon	0.06-0.30
Iron	0.10-1.20
Chromium	0.015-0.08
Nickel	0.002-0.02
Silicon	0.01-0.03

COMPARATIVE CORROSION DATA ON ZIRCONIUM
(HYDROCHLORIC ACID MILS PER YEAR)

% SOLUTION	TITANIUM		STAINLESS STEEL		HASTELLOY B		NICKEL		ZIRCONIUM	
	140F	212F	140F	212F	160F		85F	212F	140F	212F
0.5		0.35		20.4				NOT RECOMMENDED	NO ATTACK	NO ATTACK
1.0	0.11	18.5	4.41	96.5	22.8	8.76[a]	50.0			
1.5		173.0		106.0						
2.0	0.64	272.0	67.5	167.0	33.6	11.04[b]				
2.5		444.0		EXCESSIVE ATTACK						
3.0	0.38	696.0	93.5							
3.5		689.0								
4.0	42.5	938.0	92.5							
5.0	42.6	EXCESSIVE ATTACK			32.4	11.64[c]	100.0		0.06	0.09
6.0	131.0		EXCESSIVE ATTACK							
7.0	176.0									
10.0	351.0				33.6	12.0[d]	80.0		0.41	0.50
12.5	604.0									
15.0	789.0				43.2	14.4[a]	78.0			
20.0	1098.0				34.8	22.8[e]	78.0		0.52	0.69
37.0					19.2	—			0.19	0.11

[a] 225F [b] 214F [c] 216F [d] 219F [e] 230F

(Carborundum Metals Co.)



***Steam jet exhauster** fabricated from zirconium after 1-yr service handling strong hydrochloric acid and zirconium chloride fumes. Inset shows cast iron throat-piece from a similar ejector after 1-wk service.* *(Bureau of Mines)*

cellent corrosion resistance to specific environments is essential. Here it can be expected to offer real competition to tantalum, since it is not only less than half as heavy but is potentially far more abundant.

The Bureau of Mines has installed a number of zirconium parts in the pilot plant used for the production of zirconium. A zirconium part used to replace a brass part in an aspirator handling hydrochloric acid fumes extended the life from a few weeks to 2 yr. Zirconium is also being tested in shaft sleeves, steam jets and adapters for hydrochloric acid service. Zirconium spinnerets for spinning rayon fibers have been used in Europe to take advantage of the resistance of the metal to both acid and alkaline solutions.

ELEVATED TEMPERATURE PROPERTIES OF STRIP[1]

Rockwell Hardness	Temp, F	Tensile Strength, psi	Elong, % 2 in.
C 11.5	Room	87,000	16
	200	82,000	13
	400	67,000	14
C 26	Room	112,000	9
	200	102,000	8.5
	400	79,000	9.5

[1] *Cold rolled to hardness indicated.*

EFFECT OF OXYGEN AND NITROGEN ON STRENGTH

Oxygen + Nitrogen, %	Yld Str 0.2% offset, psi	Tensile Strength, psi
0.18	18,000	47,000
0.25	70,000	81,000

F. B. Litton, Iron Age, *April 5, 1951, p. 95.*

Because there is no reaction between zirconium and body fluids, the metal is being used in surgery for pins, screws and plates for skull repairs. For this service, it is considered to be superior to silver or tantalum. Other suggested uses are grid wires in vacuum tubes, electrolytic condensers, lamp filaments and electrodes in fluorescent tubes. In the form of powder, it is used as it has been for many years, as a getter in electronic tubes, for primers and for flashlight powders.

Acknowledgment

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Firth Sterling, Inc.
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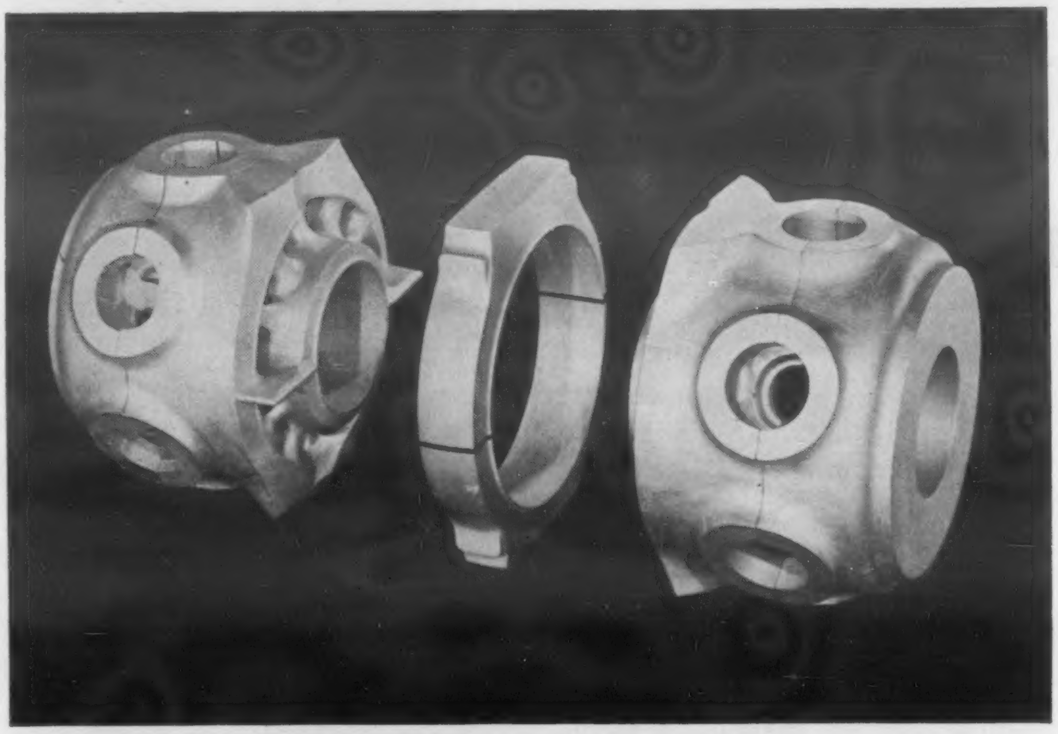
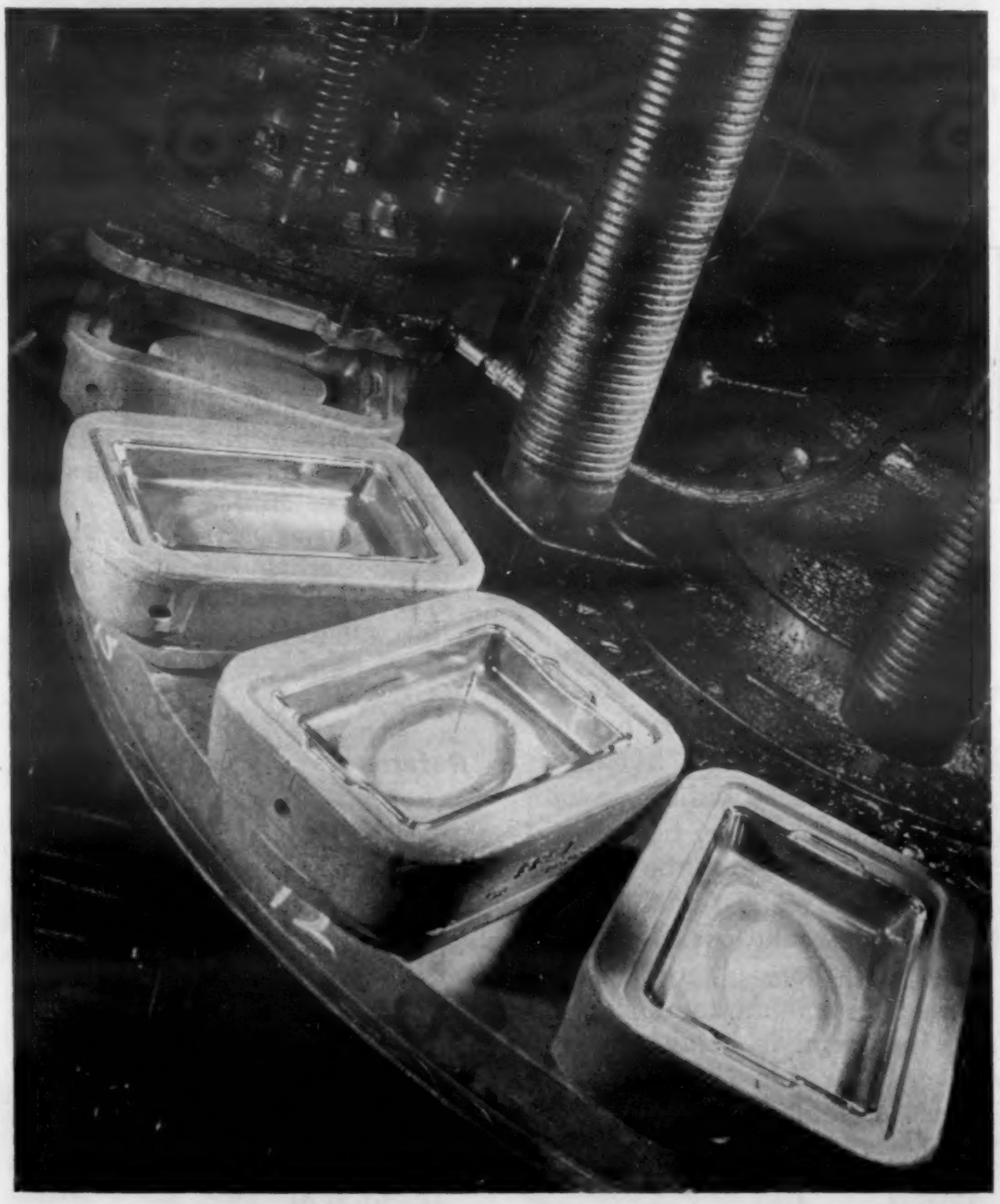
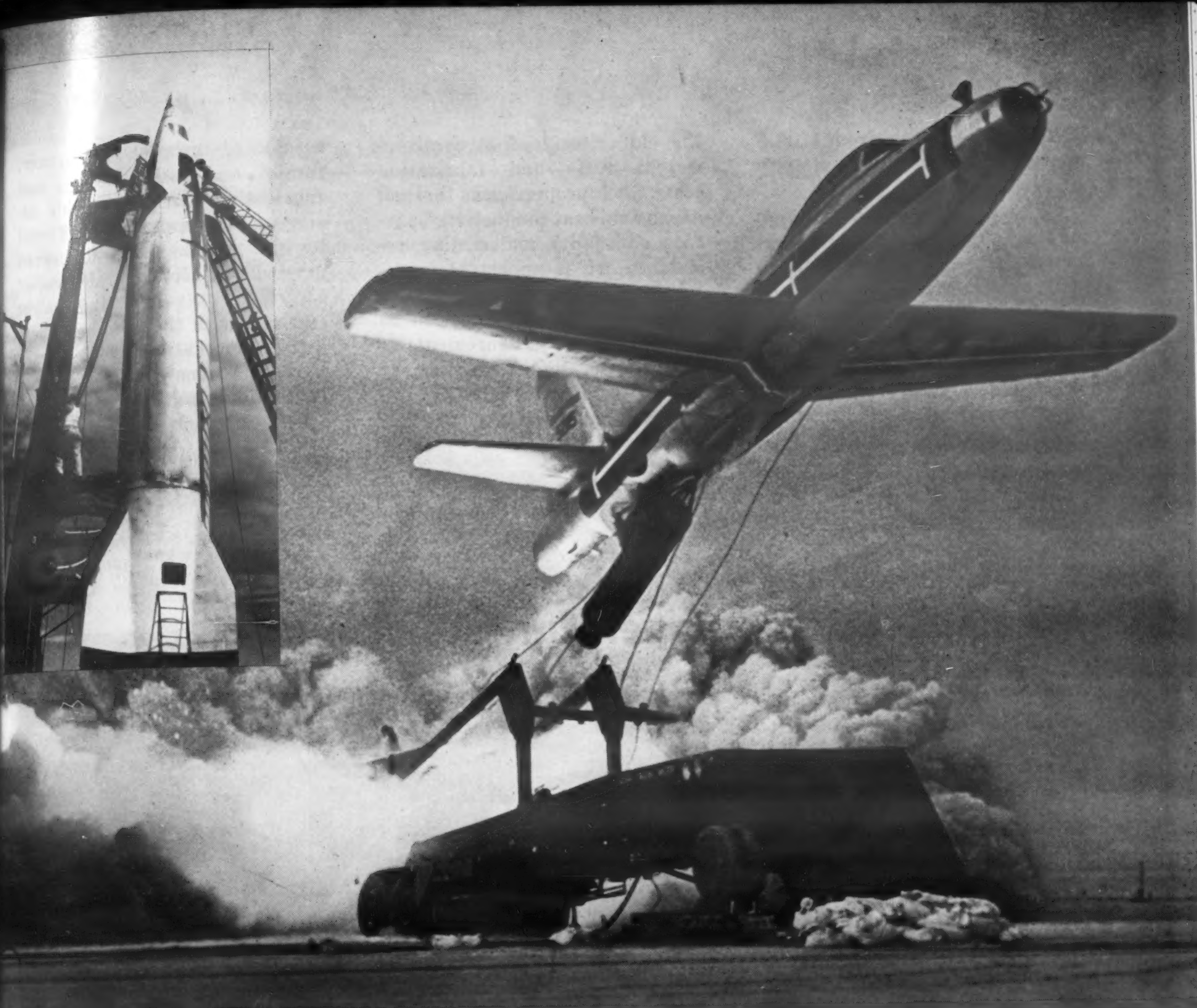




Castings Fill the Bill The castings shown here won top honors recently in the Product Development Contest sponsored by Steel Founders' Society of America. At top is a double acting compression cylinder for natural gas transmission pump. Previously cast in one piece in iron, the cylinder failed during operation at 1150 psi. Redesigned by S. S. Falk and D. P. Miller of the Falk Corp., it is now cast in two parts in plain carbon steel in the medium carbon range. The halves are welded together with a cast steel filler band to close the gap needed for welding the center bore. Smaller castings proved more sound and assembly was proof tested at 1800 psi. The redesign won first prize in Class I (SFSA members).

At bottom is contour-chilled cast stainless steel mold for forming glass. Designed by R. E. Groethe of Corning Glass Works, the cast molds replaced machined molds eliminating 100-hr machining time and saving 60% of metal by weight. Other benefits were gained in reduced quality control operations and improvements in quality of glass parts. The casting won first prize in Class II (non-members). For other winning entries see page 224.

Note: The story of selecting materials for glass-forming molds will appear in the May issue.



Metals for Short Time Service at High Temperatures

by Alan Levy, Supervisor, Material & Process Section, Marquardt Aircraft Co.

MATERIALS & METHODS MANUAL No. 115

This is another in a series of comprehensive articles on engineering materials and their processing. Each is complete in itself. These special sections provide the reader with useful data on characteristics of materials or fabricated parts and on their processing and applications.

APRIL, 1955

Selecting the right material to meet the severe service conditions encountered in aircraft power plants and rockets is a complicated matter. This manual explains the selection problem and then covers in detail the materials most suitable for:

- Turbojet Afterburners
- Ramjet Engines
- Rockets

■ The use of metals from 1200 F to temperatures in the vicinity of their melting points is a challenging and fascinating portion of the fight to pass the heat barrier in the design and performance of aircraft and their power plants. Materials available for service in this temperature range are restricted. Considerations of designing structural components involve many more problems than the old criteria of strength-to-weight ratio and fabrication costs. Such properties as thermal expansion, heat conductivity, surface emissivity and scaling resistance are as important in determining which metal should be used for a given application as are the various measurements of strength heretofore the primary factors in material selection.

This Manual is limited to a discussion of turbojet afterburner, ramjet and rocket design and fabrication. Turbojet engine design and development as affected by materials has been discussed extensively. However, design of afterburners, ramjet and rocket engines, with their higher operating temperatures and shorter lives, is a somewhat new subject that will command more attention from engineers.

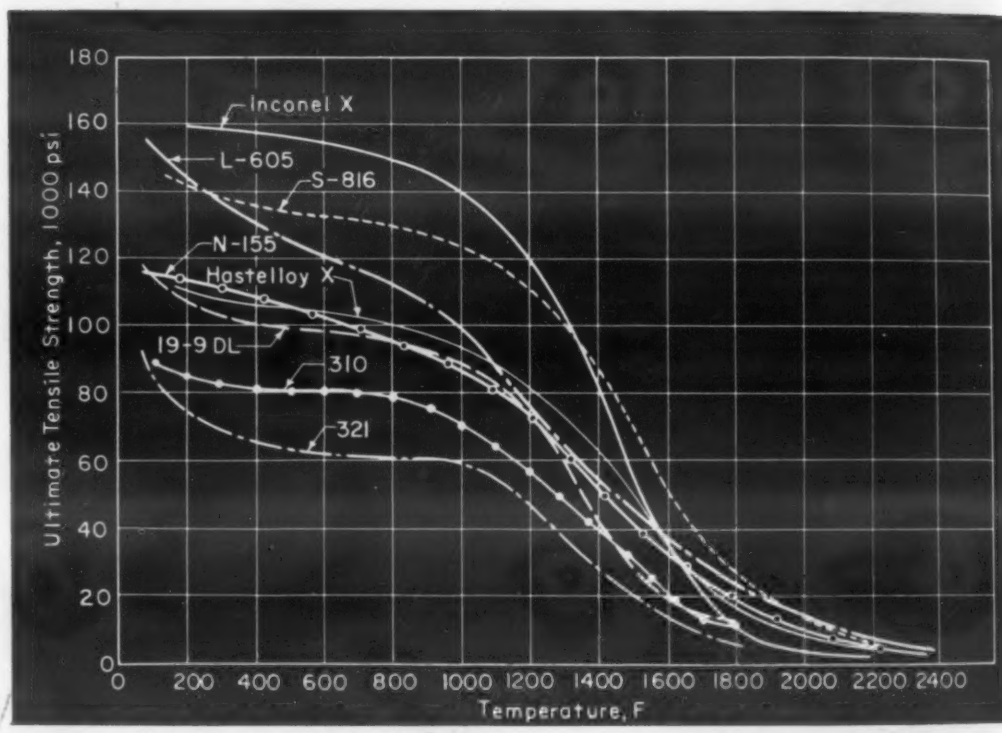
Selecting a Metal for an Elevated Temperature Application

Metals used

A primary requirement of metals and alloying elements used to produce high temperature alloys is that the resulting alloys have melting temperatures above the service temperature. In addition to this, requirements of strengthening the end-alloy, ability of elements to combine to produce ductile alloys, cost and availability of the alloying elements, and many other important factors must be considered.

Alloys that retain sufficient strength to be serviceable at temperatures above 1200 F are those having iron, nickel, or cobalt as the major constituent. Alloys based on all three of these elements are currently used in countless power plant applications. New developments in metals technology are yielding alloys based on molybdenum, titanium and possibly chromium and other metals, but at present iron, nickel and cobalt are the foundation elements for the high temperature alloy field.

In general, it can be said that alloys of iron are used in the temperature range up to 1500 F, alloys of nickel from 1500 to 1800 F, and alloys of cobalt in the range 1600 to 2200 F. Materials listed in a table are generally available. Many of the major power plant manufacturers have developed similar alloys primarily for their own products and are producing or having them produced to their own specifications.



Relationship of strength to temperature for some high temperature alloys.

Mechanical properties

The strength of a metal at elevated temperature can take several forms, dependent on the type and duration of loading. Short time tension, compression, shear and bearing strengths are of primary importance in the design of short service life power plants. The properties of creep and stress rupture are also important, especially as the service life increases. Other mechanical properties such as fatigue strength, notch-impact and notch tensile strength and modulus of elasticity must be considered in most designs. Thermal shock and thermal fatigue are also important.

The strength of metals generally decreases with increasing temperature as a result of varied elevated temperature mecha-

FUNCTIONS OF ALLOYING ELEMENTS

Element	*Function*
Iron	Foundation element for structural metals
Nickel	Base metal for high strength high temperature materials; austenitizer; improves oxidation resistance in stainless steels; adds high temperature strength; improves corrosion resistance
Cobalt	Base metal for highest strength high temperature materials; improves high temperature strength in mixed alloy materials
Chromium	Primary source of oxidation resistance
Molybdenum	Improves high temperature strength; adds corrosion resistance; has precipitation hardening potential in some alloys
Tungsten	Improves high temperature strength
Columbium	Stabilizing element in austenitic stainless steels; adds high temperature strength
Titanium	Same as columbium but has precipitation hardening value in some alloys
Aluminum	Primarily added as precipitation hardening agent
Vanadium	Thought to improve creep resistance
Silicon	Added up to about 2% to improve oxidation resistance in some stainless steels.

nisms depending on the alloy considered. Age-hardenable materials over-age, work-hardened materials anneal, while materials containing many different alloying elements form new phases at elevated temperature and can lose strength or become brittle.

Because metals lose strength at elevated temperature by several mechanisms, the service temperature and life expectancy of the component must be carefully considered before the material is chosen. Various measurements of strength must be integrated to prevent a material high in one strength property from being selected for an application where a high temperature peculiarity of the metal will result in failure. Some metals have comparatively high short time strength but considerably lower creep strength than others. Some metals have hot short or brittle ranges at certain temperatures. Others precipitate constituents in grain boundaries at certain temperatures that severely reduce their performance under load.

The variation of ultimate tensile strength with temperature for several elevated temperature alloys is shown in a graph. It is apparent that the rate of change of strength with temperature varies with the alloy. Inconel X in its heat-treated condition is the strongest material up to about 1600 F. L-605 and S-816, high-critical-alloy-content materials, retain the greatest strengths at temperatures in excess of 1600 F. Other materials, varying widely in properties, fall below these three in strength at elevated temperatures. A summary of short-time tensile properties of typical materials in the various alloy classes is given in a table.

Strengths of all these materials at 1800 F or above are low. However, many of the high temperature components of afterburners and ramjet engines can be designed to function at temperatures up to 2200 F for short

Martin Matador pilotless bomber *powered by a turbo-jet engine and aided by a rocket-assisted-takeoff bottle makes use of high temperature alloys.*

SUMMARY OF SHORT TIME MECHANICAL PROPERTIES OF ELEVATED TEMPERATURE ALLOYS

Alloy	Room Temperature			1000 F			1200 F			1400 F			1500 F			1600 F		
	Ten Str, 1000 psi	Yld Str, 1000 psi	Elong, % 2 in.	Ten Str, 1000 psi	Yld Str, 1000 psi	Elong, % 2 in.	Ten Str, 1000 psi	Yld Str, 1000 psi	Elong, % 2 in.	Ten Str, 1000 psi	Yld Str, 1000 psi	Elong, % 2 in.	Ten Str, 1000 psi	Yld Str, 1000 psi	Elong, % 2 in.	Ten Str, 1000 psi	Yld Str, 1000 psi	Elong, % 2 in.
19-9DX	130	102	26	95	77	20	80	70	20	53	50	24	39	33	43	—	—	—
19-9DL	118	69	58	89	42	43	75	39	34	43	36	36	33	30	53	18	—	56
16-25-6	114	68	42	93	42	35	88	40	36	53	33	42	41	30	49	30	—	57
Discalloy 24	145	106	19	125	94	16	104	91	19	73	60	14	—	—	—	—	—	—
321	92	39	55	61	27	35	46	25	34	28	15	70	22	13	73	14	11	82
310	82	40	55	67	26	50	48	23	24	42	21	27	32	19	37	24	17	43
L-605	155	70	55	100	35	67	75	35	25	53	37	14	50	—	17	37	34	18
Hastelloy B	135	63	44	109	42	31	94	42	16	77	40	16	66	—	17	55	39	19
Hastelloy C	130	54	38	97	55	22	87	50	23	63	47	32	51	—	36	38	36	39
Hastelloy X	113	56	44	94	42	45	83	41	37	63	38	37	52	37	33	37	26	50
Inconel X	162	92	24	140	84	22	120	82	9	80	62	—	52	44	22	34	24	47
Nimonic 75	92	60	50	—	—	—	—	—	—	46	20	28	36	15	33	—	—	—
Nimonic 80	—	—	—	108	73	41	88	73	15	67	63	7	60*	47*	9	—	—	—
Nimonic 90	148	90	39	123	82	27	111	77	24	90	63	14	64	52	8	—	—	—
N-155	116	57	43	85	—	37	72	40	35	50	35	38	37	33	39	32	24	42
S-590	118	72	—	128	79	—	100	70	—	65	50	—	52	47	—	40	37	—
S-816	140	63	31	121	46	27	112	45	22	88	40	25	73	41	23	51	—	17
Refract 26	153	96	18	142	91	17	134	95	14	108	90	13	73	72	28	48	48	49
Refract 70	133	—	—	117	—	—	104	—	—	83	—	—	64	—	—	50	—	—
Inconel	91	37	47	84	29	47	65	27	39	28	17	46	—	—	—	15	9	80
Inconel W	146	81	—	123	72	—	117	62	—	—	—	—	—	—	—	—	—	—

All above values are for material in annealed condition except: 19-9DX, 19-9DL—Hot rolled and stress relieved. Inconel X, Inconel W—Aged. Nimonic 80, 90—Aged. Discalloy 24—Aged. 16-25-6—Hot Rolled. Refract 26, 70—Aged. S-816, S-590—Aged.

times. It is essential that the strength be known at these temperatures to permit use of compensating increased thicknesses. Unfortunately, data at the higher temperature levels are rather limited. Haynes Stellite recently reported data on short-time tensile properties up to 2400 F on several alloys.

Short-time (to 1000 hr) creep and stress rupture strengths for alloys commonly used in afterburner and ramjet engine construction have also been compiled. Much additional work is necessary on creep and stress rupture properties to satisfy the designers of guided missiles and guided missile power plants.

Physical properties

In addition to mechanical properties, physical properties such as coefficient of thermal expansion, thermal conductivity, emissivity, etc. become important factors in elevated temperature service.

Thermal stresses resulting from differential expansion of parts subjected to different temperatures or the differential expansion at a joint between metals having different coefficients of thermal expansion can produce 50% or more of the total applied load on the part. Many cases of failure resulting from differential thermal expansion are on record. In general, a low coefficient is desired. However, equally important, in the case of dissimilar metal joints, is an equivalent coefficient of thermal expansion, high or low.

Thermal conductivity becomes critical in applications such as combustion chambers where it is important that heat be rapidly distributed and dissipated. This is especially true where uneven combustion produces hot spots. Since most high temperature alloys have comparatively low thermal conductivity, differential heating and hot spots can easily lead to severe distortion and ac-

CREEP STRENGTH FOR SOME ELEVATED TEMPERATURE ALLOYS (IN 1000 PSI)

Temp, F	Elong, % Per Hr	321	310	19-9 DL	Inconel X	Hast C	Hast X	N-155	S-816	L-605
1200	0.01	—	—	22.0	82.0	—	30.0	—	62.0	—
	0.001	9.5	—	21.0	73.0	—	—	—	52.0	—
	0.0001	8.0	8.6	20.0	64.0	—	—	—	42.0	—
1350	0.01	—	—	16.0	55.0	—	18.5	34.4	39.5	33.0
	0.001	—	—	13.0	47.0	—	9.5	25.0	26.8	26.0
	0.0001	3.0	4.0	10.0	38.0	—	—	18.4	18.0	—
1500	0.01	—	—	15.3	30.1	—	11.0	18.3	23.2	21.0
	0.001	—	—	10.4	19.6	—	7.0	13.8	16.4	17.0
	0.0001	1.0	1.0	7.1	12.3	—	—	10.3	11.5	—
1600	0.01	—	—	—	13.0	—	5.0	—	12.3	16.0
	0.001	—	—	—	11.0	—	3.2	—	8.5	12.5
	0.0001	—	—	—	9.0	—	2.4	—	5.8	—

1800 F			2000 F		
Ten Str, 1000 psi	Yld Str, 1000 psi	Elong, % 2 in.	Ten Str, 1000 psi	Yld Str, 1000 psi	Elong, % 2 in.
13	10	85	—	—	—
13	—	61	—	—	—
18*	—	59*	—	—	—
—	—	—	—	—	—
5*	—	—	—	—	—
11	—	55	7	—	63
23	—	19	14	—	22
24	—	30	—	—	—
19	—	38	12*	—	30*
21	17	43	16 at 1900F	—	—
9	6	89	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—
17	12	38	12	7	30*
22	20	—	13	14	—
25	—	20	12	—	24
—	—	—	—	—	—
—	—	—	—	—	—
8	4	118	—	—	—
—	—	—	—	—	—

STRESS RUPTURE OF SEVERAL HIGH TEMPERATURE ALLOYS (IN 1000 PSI)

	Time (hr)	321	310	19-9 DL	Inconel X	Hast C	Hast X	N-155	S-816	L-605
1000 F	1	—	—	—	—	—	—	—	—	—
	10	—	—	—	122.0	—	—	—	—	—
	100	—	—	—	115.0	—	—	—	—	—
	1000	—	32.0	—	110.0	—	—	—	—	—
1200 F	1	33.0	38.3	—	—	—	—	—	100.0	—
	10	31.0	—	70.0	92.0	—	58.0	80.0	80.0	—
	100	25.0	27.0	60.0	80.0	53.0	45.0	60.0	62.0	45.0
	1000	17.5	13.7	40.0	55.0	35.0	30.0	46.0	50.0	—
1400 F	1	—	—	—	—	—	—	—	—	—
	10	—	—	45.4	52.0	—	30.0	33.0	45.0	40.0
	100	—	—	28.0	42.0	—	21.0	25.7	32.0	30.0
	1000	5.6	5.1	16.5	33.0	—	16.0	19.5	27.0	23.0
1500 F	1	20.0	—	—	—	—	—	—	43.0	—
	10	12.0	16.6	18.0	38.0	—	21.0	33.0	35.0	35.0
	100	3.8	8.3	13.0	30.0	15.0	14.0	20.0	29.0	22.0
	1000	3.7	3.5	10.5	18.5	9.5	10.0	15.0	22.0	18.0
1600 F	1	—	—	—	—	—	—	—	—	—
	10	—	—	—	17.0	—	16.0	18.0	20.0	24.0
	100	—	—	—	11.0	—	8.0	15.0	15.0	15.0
	1000	—	2.4	—	6.6	—	6.0	7.3(1650)	10.0	11.0
1800 F	1	—	6.3	—	—	—	—	10.0	—	—
	10	4.8	—	—	—	—	7.0	8.8	8.8	13.0
	100	2.9	—	—	—	4.0	3.4	3.3	5.5	7.0
	1000	—	1.0	—	—	1.4	—	2.8	3.1	4.5
1900 F	1	—	—	—	—	—	—	—	—	—
	10	—	—	—	3.2	4.5	3.0	—	5.7	—
	100	—	—	—	1.7	2.7	—	—	3.2	—
	1000	—	—	—	—	—	—	—	—	—

All materials in annealed condition except 19-9DL-stress relieved at 1200 F and Inconel X-aged.

PHYSICAL PROPERTIES OF SEVERAL ELEVATED TEMPERATURE ALLOYS

Material	321		310		19-9DL		Inconel X		Hastelloy C		Hastelloy X		N-155		S-816		L-605	
Density, lb/cu in.	0.290		0.290		0.287		0.298		0.322		0.297		0.300		0.313		0.330	
Melting Point, F	2575		2600		2600		2540		2350		2400		2500		2400		2570	
Mean Coefficient of Thermal Expansion, /°F x 10^{-6}	Temp, F	Coef	Temp, F	Coef	Temp, F	Coef	Temp, F	Coef	Temp, F	Coef	Temp, F	Coef	Temp, F	Coef	Temp, F	Coef	Temp, F	Coef
	32–212	9.3	32–212	8.0	70–212	8.2	100–200	7.6	70–600	7.02	79–200	7.70	70–600	8.70	70–600	6.6	70–600	7.61
	32–600	9.5	32–600	9.0	70–600	8.7	100–400	7.7	70–800	7.35	79–400	7.82	70–800	8.89	70–800	6.9	70–800	8.28
	32–1000	10.3	32–1000	9.4	70–1000	9.5	100–600	7.9	70–1000	7.44	79–600	7.90	70–1000	9.10	70–1000	7.1	70–1000	8.30
	32–1200	10.7	32–1200	9.7	70–1200	9.7	100–800	8.0	70–1200	7.73	79–800	8.15	70–1200	9.40	70–1200	7.4	70–1200	8.55
	32–1800	11.2	32–1800	10.6	70–1600	10.2	100–1000	8.2	70–1500	8.07	79–1000	8.39	70–1500	9.77	70–1400	7.7	70–1400	8.92
	—	—	—	—	70–1800	10.5*	100–1200	8.4	70–1600	8.20	79–1200	8.56	70–1600	9.90	70–1600	8.0	70–1600	9.30
	—	—	—	—	70–2000	11.0*	100–1350	8.7	—	—	79–1350	8.76	—	—	70–1800	8.3	70–1800	9.70
	—	—	—	—	—	—	100–1500	9.0	—	—	79–1500	8.92	—	—	—	—	—	—
	—	—	—	—	—	—	100–1600	9.2	—	—	79–1650	9.07	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	79–1800	9.20	—	—	—	—	—	—
Coefficient of Thermal Conductivity, Btu/sq ft/in./hr/°F	200	112	200	96	200	101	Room	85	—	—	—	—	392	101	302	101	Room	85
	600	—	600	—	600	117	600	137	—	—	—	—	572	110	572	119	600	91
	1000	152	1000	130	1000	134	1000	144	—	—	—	—	752	120	932	142	800	98
	—	—	—	—	1200	143	1200	156	—	—	—	—	932	129	1112	155	1000	100
	—	—	—	—	1400	150	1400	168	—	—	—	—	1112	139	1292	155	1200	102
	—	—	—	—	1600	163	1600	180	—	—	—	—	—	—	—	—	1400	103
	—	—	—	—	—	—	1800	195	—	—	—	—	—	—	—	—	1600	112
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1800	116
Modulus of Elasticity, Psi x 10^6	Room	29.0	Room	29.0	Room	29.4	Room	30.8	Room	28.5	—	—	Room	29.3	Room	35.2	—	—
	200	28.0	200	28.2	200	28.4	200	30.4	1200	26.8	—	—	200	—	300	33.8	—	—
	600	25.2	600	25.7	600	25.5	600	28.1	1500	22.0	—	—	600	—	600	31.9	—	—
	1000	22.5	1000	23.2	1000	24.5	1000	25.0	1800	18.7	—	—	1000	24.2	900	29.7	—	—
	1200	21.1	1200	22.0	1400	20.5	1200	23.0	—	—	—	—	1200	—	1050	28.7	—	—
	1400	19.8	1400	20.8	1600	19.3*	1400	20.2	—	—	—	—	1500	20.8	1200	27.6	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1500	25.4	—	—

* *Extrapolated values.*

tual burning of the metal. Thermal stresses causing failure are often the result of inability to distribute heat evenly throughout a part.

A property only recently considered seriously by the power plant designer is emissivity. It is important in combustion chambers to have an inside surface with as low an emissivity factor as possible, in order to reflect the maximum radiated heat from the combustion gases. On the other hand, a ramjet engine combustion chamber outer surface is open to the sky and should have as high an emissivity factor as possible to radiate more heat from the wall to the sky. The factor of emissivity can result in hundreds of degrees difference in operating wall temperatures.

Critical alloy content

The available supply in the U.S.A. of many of the alloying elements used in high temperature alloys is limited either by the scarcity of the element in the earth, by an overseas source, or both. The amount of an element available in this country at the time of a national emergency can be critical. For this reason, the government has stressed the importance of minimum critical alloy content in the designs of power plants for piloted aircraft and missiles. Since the end of the Korean War, the supplies of critical alloys have increased measurably. However, the principle of minimum critical alloy content must be practiced continuously. Some of the alloying elements used in high temperature alloys that have been in critical supply in the past few years are nickel, cobalt, columbium, molybdenum, chromium and tungsten. The changing supply picture continues to modify this list. Stock-piling also has an effect on present and future critical alloy supplies. It is apparent that practically all of the elements that are used in high temperature alloys have been or are considered in critical supply.

SOME COMMON HIG

*Iron Base Alloys**	
Type 321, 347	These materials are stabilized 18:8, basic non-hardenable stainless steel. They have excellent fabrication characteristics, are weldable and fully corrosion resistant. Are commonly used in elevated temperature applications to 1500 F where medium strength and corrosion resistance is required.
Type 310	A standard AISI steel which contains 25% chromium and 20% nickel. This material has excellent scaling resistance up to 2000 F and over. Is used where high strength is not needed at temperatures to 2200 F.
19-9DL, 19-9DX	A modified stainless steel containing molybdenum and tungsten. It retains strength comparable with most of the high temperature alloys up to 1400-1500 F. An excellent low critical alloy index material for general structural use up to 1500 F.
16-25-6	A chromium, nickel, molybdenum alloy available in bars and forgings. This alloy has been a commonly used turbine wheel material for service up to about 1500 F.
A-286	An age-hardenable stainless steel that can be used up to the low end of the temperature range, around 1200 F.
17-4 PH, 17-7 PH	Age-hardenable stainless steels having high strength-weight ratios at lower temperatures, but that find some application in the temperature range around 1000 F.
Discalloy 24	An age-hardenable stainless steel primarily used as a forged wheel alloy up to 1300 F.
Nickel Base Alloys	
Inconel	An 80% nickel, chromium, iron alloy that has seen much use as a low strength, high corrosion resistant material at elevated temperatures. It is hot-short (low ductility) at 1200 F and is not commonly used in powerplant structures today.
Inconel X	An age-hardenable modification of Inconel containing titanium and aluminum that has the highest strength up to 1600 F of all high temperature alloys. It is difficult to fabricate, must be heat treated after forming. It has found wide-spread use as a combustion chamber material for afterburners as well as many other applications.
Incoloy	A modification of Inconel X having reduced

Fabrication characteristics

In general, high temperature alloys present greater fabricating difficulties than either low alloy or stainless steels. Since the fabrication characteristics of 18:8 stainless steels have been fairly well documented, it is a common practice to compare the high temperature alloys with

	critical alloy content and somewhat lower properties.
Nimonic 75, 80, 90	A series of British developed alloys similar to Inconel X in composition and function.
Hastelloy B	A Haynes Stellite development containing molybdenum as the major alloying element, and no chromium. The absence of chromium and high percentage of molybdenum lowers its scaling temperature. It has excellent strength to 1600 F and higher.
Hastelloy C	Another Haynes Stellite product that contains chromium for increased scaling resistance and has been used for high strength applications to 1800 F and above. However, its high critical alloy content and fabrication characteristics limit its use.
Hastelloy X	A critical alloy reduced version of other Hastelloys that combines excellent scaling resistance with good strength. It is being used more and more in combustion chamber and component applications of all power plants.
Cobalt and Mixed Base Alloys	
N-155 (Multimet)	A chromium, nickel, cobalt, iron mixed base alloy that has become somewhat of a work horse in the temperature range from 1200 F up. It has good high temperature properties to 2000 F, compared with other alloys, can be readily fabricated, requires no heat treatments.
S-816	A mixed base alloy with 3% or higher columbium, tungsten and molybdenum. It is high on the critical alloy list, has excellent strength at the higher temperatures. It has been used extensively for forged turbine blades.
Refractaloy 70	A mixed base alloy with high molydenum that has good elevated temperature properties. It is not widely used.
L-605 (H.S. 25)	A cobalt base material that is the strongest of all high temperature alloys above about 1600 F. It is only used where high stresses exist at the upper end of the temperature range (1700-2200 F). High critical alloy content.
H.S. 21, 23, 30, 31, etc.	A series of cobalt base casting alloys. They are commonly used for cast turbine blades and other high temperature applications requiring high strength.

****Iron base alloys available in all shapes and forms unless specifically noted.***

stainless steels when considering the various fabrication methods.

Welding—All of the high temperature alloys can be fusion welded satisfactorily. Inert-gas-shielded arc welding is best for most of the alloys because this process offers the least chance of contamination by carbon and oxides. Use of flux coated rods or liquid or paste fluxes introduces the problem of complete flux removal prior to elevated temperature service. Finish configuration of welds, especially in sheet material, has a great effect on the performance at elevated temperatures. For this reason, the optimum welded joint is a tight butt weld made automatically by the inert-gas-arc method adding no filler metal and roll leveling the resultant bead. Roll leveling mechanically forces the weld metal into the plane of the base metal producing a flush, cold-worked joint. Resistance welded joints are readily made using somewhat greater pressures than are necessary for stainless steel.

Forming — High temperature alloys can be formed by all of the commonly used forming techniques. They tend to work harden rapidly and require roughly twice the number of intermediate anneals as stainless steels. Minimum bend radii are somewhat larger than those for stainless steels and provision must be made for greater springback. Annealing generally requires temperature above 2000 F and involves high temperature furnaces and special equipment for removing scale.

Machining—The high temperature alloys are hard to machine. In general, the mixed base and cobalt base materials are most difficult, the nickel alloys next, and the iron alloys the easiest to machine. A good value for estimating the speed of machining high temperature alloys is 1/3 to 1/2 the speed for stainless steels in all normal cutting operations, e.g. milling, drilling, shaping.

Forging—Forging is possible on practically all the high temperature alloys. However, forging pressures and temperatures must be higher than for stainless steels. Tolerances in the as-forged condition may not quite compare with those of stainless steel or alloy steel parts because of the more difficult working conditions.

Casting—Many of the high temperature alloys are cast by

SURFACE EMISSIVITY

Iron and Steel	Temp Range, F	Emissivity
METALLIC SURFACE		
Polished Iron	800–1800	0.144–0.377
Cast Iron, Polished	392	0.21
Wrought Iron, Polished	100–480	0.28
Cast Iron, Newly Turned	72	0.435
Polished Steel Casting	1420–1960	0.52–0.56
Ground Sheet Steel	1720–2010	0.55–0.61
Smooth Sheet Iron	1650–1900	0.55–0.60
Cast Iron, Lathe Turned	1620–1810	0.60–0.70
OXIDE SURFACE		
Iron Plate, Pickled, then Rusted Red	68	0.612
Completely Rusted	67	0.685
Rolled Sheet Steel	70	0.657
Oxidized Iron	212	0.736
Cast Iron, Oxidized at 1100 F	390–1110	0.64–0.78
Steel, Oxidized at 1100 F	390–1100	0.79
Smooth Oxidized Electrolytic Iron	260–980	0.78–0.82
Iron Oxide	930–2190	0.85–0.89
Rough Ingot Iron	1700–2040	0.87–0.95
Sheet Steel, Strong, Rough Oxide Layer	75	0.80
Sheet Steel Dense, Shiny, Oxide Layer	75	0.82
Cast Iron, Rough, Strongly Oxidized	100–480	0.95
Wrought Iron, Dull Oxidized	70–680	0.94
OTHER ALLOYS		
18:8 Stainless Steel Sandblasted	180–350	0.5
18:8 Stainless Steel Oxidized at 1000 F	180–340	0.32–0.36
18:8 Stainless Steel Oxidized at 1500 F	165–330	0.63–0.69
Inconel Untreated	193–250	0.16–0.20
Inconel Oxidized at 1400 F	185–340	0.19
Monel	1000	0.10
Monel—Oxidized	1000	0.46
PIGMENTS		
Black Lacquer	750	0.95
Black (CuO)	750	0.85
Red (Fe_2O_3)	750	0.70
Green (Cr_2O_3)	750	0.67
Yellow (PbO)	750	0.49
White (MgO)	750	0.84
White (ZrO_2)	750	0.77

Emissivity is a measurement of the amount of incident radiant heat that can be absorbed into or leave a given surface. Properly speaking, emissivity is the ratio or heat radiated by a body to that radiated by a black body at the same temperature. For common combustion chamber materials, emissivity is numerically equal to absorptivity. An emissivity factor of 1 is that of a black body which will absorb or radiate the maximum amount of heat.

several of the casting methods. When complicated parts are desired from hard-to-machine alloys like Haynes Stellite 21, 23, or 31, the parts are investment cast to finished shape. Turbine blades and afterburner nozzle segments are typical of parts that are cast in this manner. Many of the cobalt base alloys are fabricated only by casting.

Scaling and corrosion resistance

As the service temperature of a part climbs to above 1500 F, scaling becomes an important factor in determining the choice of materials. In addition, the corrosive effects of hot combustion gases on burner components must be considered. Chromium content is the best, but not the only, indication of scaling resistance. Chromium contents of 15 to 20% in high temperature alloys will result in scaling resistance up to 1800 or 1900 F. Increase in chromium content to 25%, as in type 310 stainless steel, increases free scaling temperature to 2200 F. At and above this temperature, all alloys have a decided scaling rate.

Service life expected of afterburners limits their top metal temperature to about 1900 F. However, since scaling is determined by temperature, atmosphere and time, the short service lives required of guided missile power plants enable parts to function at temperatures of 2000 F and higher. Thus, the much shorter service life of ramjet engines extends their top operating temperatures to 2000-2200 F. Probably the two best scaling resistant materials available today are type 310 stainless steel and Hastelloy X, primarily because of high chromium content.

Price

The price of most high temperature alloys is considerably above that of low alloy and stainless steels. Expensive alloying elements and special melting and mill practices necessary to produce high quality finished products contribute to increased cost. However, the material needs of modern high operating temperature power plants can only be satisfied by the high temperature alloys. Therefore, cost is usually a minor consideration. Typical prices for some of the commonly

TYPICAL COST OF SHEET MATERIALS

	$ per lb
LOW ALLOY STEELS	
AISI 1020	0.10
AISI 4130	0.20
STAINLESS STEELS	
AISI 302	0.60
321	0.75
310	0.90
17-7 PH	0.85
HIGH TEMPERATURE ALLOYS	
19-9DL	1.10
Multimet (N-155)	2.50
Hastelloy X	2.50
Inconel X	2.50
Hastelloy C	3.50
H. S. 25 (L-605)	5.50

used high temperature alloys are compared with stainless and low alloy steels in a table.

Elevated temperature limitations of metals

Strength — Useable strength levels for high temperature alloys vary with the application. For short time applications under light loads and a simple stress pattern, service temperatures as high as 2200 F have been considered for structural components of ramjet engines. In other applications, such as in high speed, long service life turbine blades, 1600 F is considered about the top temperature today. Each application must be rated with respect to load, service time and other factors in determining a ceiling temperature. Many times an alloy can be used for intermittent, short time service at temperatures considerably above the normal operating temperature. For all high temperature applications, it is important to know the rate of change of strength with temperature. These data are just becoming available. Work by Armour Institute, Haynes Stellite, and other organizations on short time properties of alloys, and Battelle Memorial Institute on creep and stress rupture have been important contributions to missile power plant design. Some of the newer data are summarized in tables.

Melting point — Combustion temperatures using known fuels are now above the melting points of the highest melting metals. Most of the refractory metals with melting temperatures over 3000 F are brittle and susceptible to rapid oxidation. The melting point of the basic structural metal, iron, is 2800 F. As alloying elements are added, this temperature is reduced. Cobalt and nickel melt below 2800 F, their alloys melt in the range 2400-2600 F. In general, all present structural materials capable of unprotected operation at temperatures above 1500 F melt below 2700 F. To the combustion engineer, 2700 F is a low gas temperature.

***Rocket power plant** requirements are severe but short life of the component permits use of materials which are not normally considered suitable for high temperature service.* *(National Advisory Committee for Aeronautics)*

Research to produce ductile alloys of molybdenum, chromium, titanium, and zirconium for service at temperatures above 2000 F is progressing slowly. The high melting points of these elements, all above 3000 F, are offset by lack of oxidation resistance, lack of strength, brittleness, production or fabricating difficulties.

Molybdenum (m.p., 4750 F) catastrophically oxidizes at about 1800 F, tends to produce brittle alloys and is very difficult to fabricate, especially to weld. While it is anticipated that molybdenum alloys will eventually be available that have tensile strengths of 20,000 psi at 2400 F, much research work must still be done. Alloys of titanium (m.p. about 3100 F) in current produc-

tion drop markedly in strength above about 1000 F and embrittle when exposed in air to temperatures above 1400 F. Chromium (m.p. about 3400 F) and its alloys investigated to date are too brittle for structural applications.

Most of the other high melting metals are so brittle or susceptible to scaling or both that development work on structural alloys of tungsten, rhenium, tantalum and similar elements for high temperature service in air, is nonexistent. Therefore, it can be stated that we are nearing the ultimate in high temperature structural metals at service temperatures considerably below the combustion gas temperatures known today. Cermets and refractory hard metals (silicides, borides, carbides, nitrides, etc.) seem to be the principal hope of the future.

EXPERIMENTAL HIGH TEMPERATURE PROPERTIES

Temp, F	Hastelloy X		Multimet (N-155)		No. 25 Alloy (L-605)	
	Ult Ten Str, 1000 psi	Elong, % 2 in.	Ult Ten Str, 1000 psi	Elong, % 2 in.	Ult Ten Str, 1000 psi	Elong, % 2 in.
1800	15.3	42	19.2	61	22.3	43
1800	15.2	50	19.5	55	23.9	44
2000	9.3	41	9.4	45	12.8	31
2000	9.3	37	9.4	46	12.9	28
2200	4.7	43	4.6	29	6.8	17
2200	4.6	37	4.6	26	6.8	10
2300	3.4	21	3.4	18	4.6	16
2300	3.3	20	3.4	19	4.6	9.5
2350	2.5	2	2.5	6.5	—	—
2350	2.6	8	2.7	7	—	—
2400	.7	1	.4	0	3.0	6
2400	—	—	—	—	3.1	5

All material annealed sheet, held at test temp 15 min before loading.

Applications in Turbojet Afterburners

Afterburners are being used for short periods in conjunction with turbojet engines to obtain additional thrust during take-off and at other times when it is deemed necessary. Fundamentally, an afterburner is a device that injects additional fuel into the exhaust of the turbojet to use the excess oxygen present. An afterburner is composed of a fuel injector, a flameholding device, a combustion chamber and a variable area exit nozzle. The present Air Force specification for afterburners requires each model to pass a qualification test consisting of 150 hr of operation including 22 hr of afterburning.

Combustion chambers

The combustion chamber of a typical afterburner is a single or double wall cylinder produced from high temperature alloy sheet usually less than 0.1 in. thick. Dimensions range from 60 to 120 in. long and from 32 to 42 in. in diameter. During afterburner operation, the wall temperature of a single wall chamber reaches temperatures from 1500 to 1650 F in the burning area. The service life and loads require that a material such as N-155 be used in the forward regions and L-605 in the exit area. These materials, in thicknesses ranging from 0.050 in. to 0.070 in., are rolled into cylinders or cones and fusion welded. Welds must be practically flush to prevent hot spots from forming due to weld bead projection into the hot combustion gases.

Double wall chambers are usually corrugated to allow cooling air to pass between them. Several double wall chamber designs have been fabricated from Inconel W or X. These materials have high strengths at service temperatures of 1300 F for the outer wall, 1600 to 1800 F for the inner wall. Relatively high final aging temperatures and times required to obtain maximum strength in these alloys create a heat treating production problem because the chambers are comparatively large. Fabricating the corrugations in these alloys is also a production problem. However, comparatively thin metal can be used with resulting minimum weight.

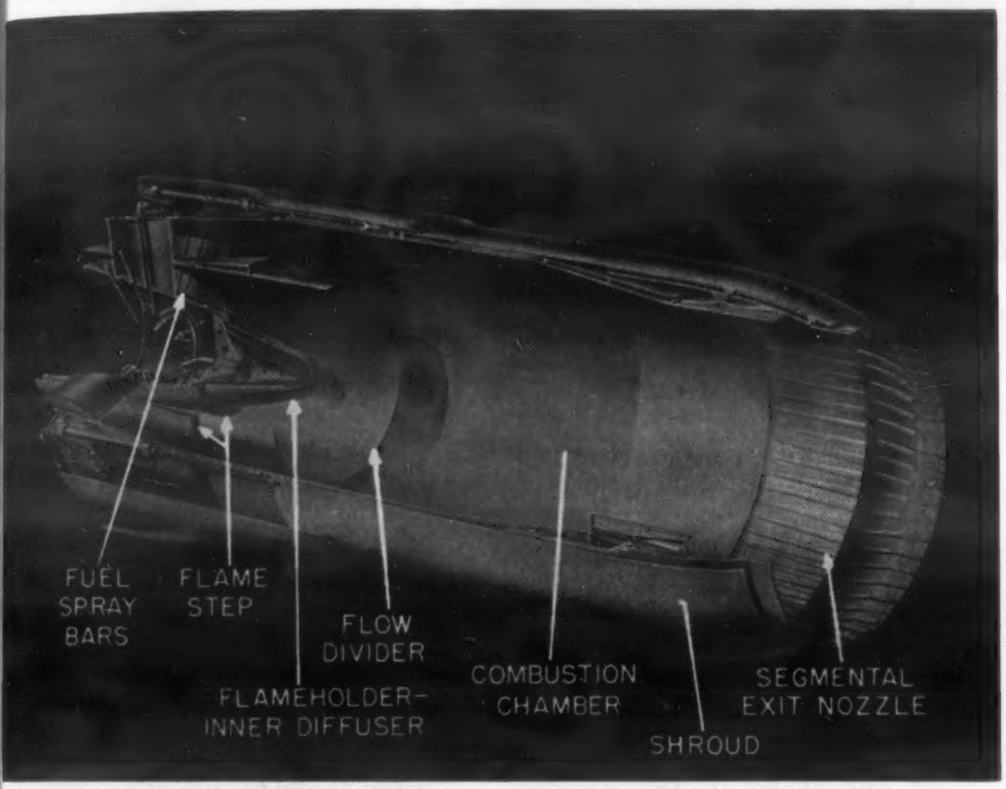
Flameholders

Flameholders of afterburners are subjected to the highest service temperatures in the unit, reaching 1800-1900 F during afterburning at and near the flame step. Thermal stresses induced by differential heating, build up of temperature caused by radiation from one surface to another, and high collapsing pressures for the service temperatures tend to cause premature failure unless some cooling method is incorporated in the design.

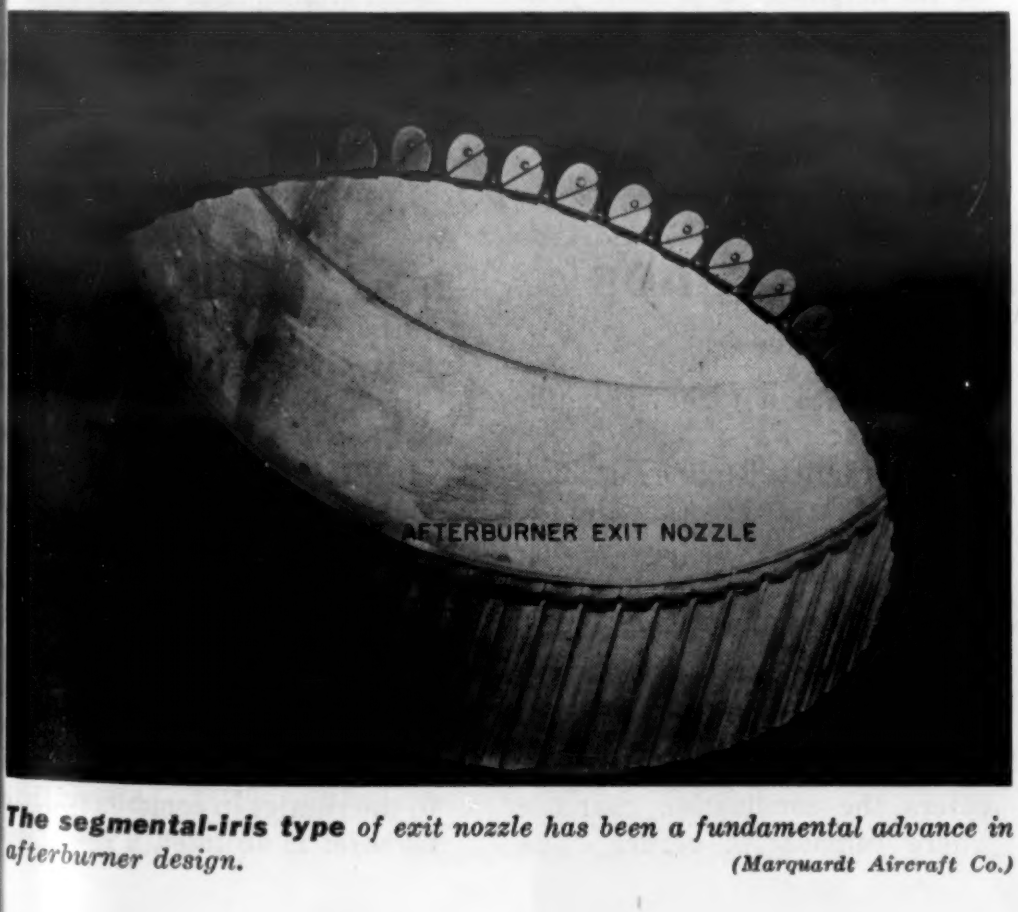
A typical afterburner flameholder consists of two developed surface truncated sheet metal

cones with a flame step between them. The large cone is fabricated from 0.050 in. N-155 while the smaller inner cone from 310 stainless steel. Cones are spun or rolled into shape and fusion welded together. The flame step is the hottest area of the flameholder, and the point where scaling and differential thermal expansion resulting in high thermal stresses are critical design considerations.

Under present practice the step is machined from a 310 stainless steel forging into an annular cup shape to reduce thermal stresses. Cooling air from the turbine exhaust at 1200 F is passed along the inside walls of the sheet metal cones to cool them and maintain a uniform temperature. Hastelloy X is being considered as a replacement for 310 stainless steel components of flameholders to take advantage of its greater strength at temperatures around 2000 F and equal scaling resistance.



***An afterburner** is composed of a fuel injector, a flameholding device, a combustion chamber and a variable area exit nozzle.* *(Marquardt Aircraft Co.)*



***The segmental-iris type** of exit nozzle has been a fundamental advance in afterburner design.* *(Marquardt Aircraft Co.)*

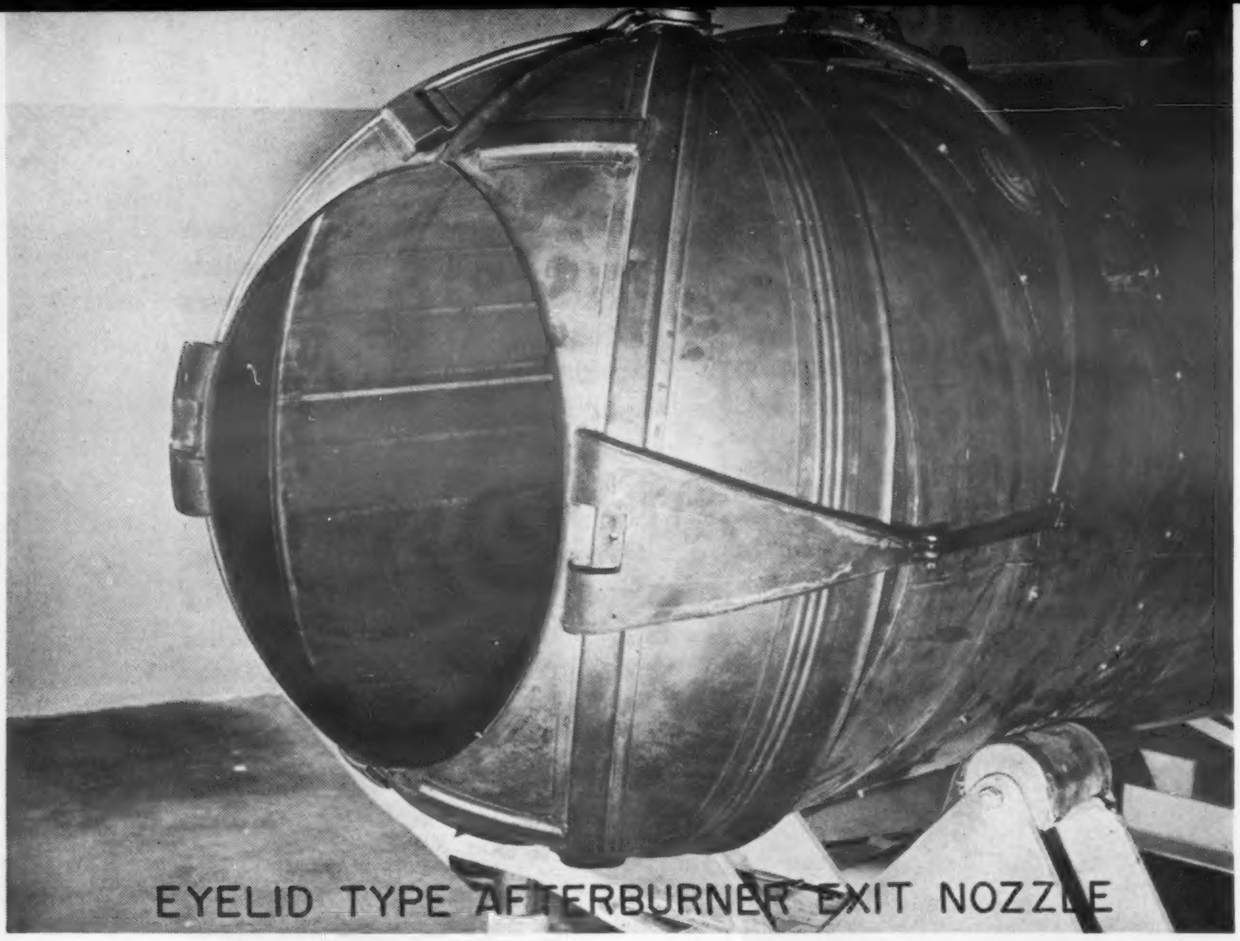
Fuel spray bars

Fuel is introduced into an afterburner through a series of single or multiholed radial fuel spray bars placed upstream from the flameholder. These bars consist of 321 or 310 stainless steel, or N-155 tubes about 0.060 in. in wall thickness and 10 in. long that have been flattened into an elliptical shape. Holes drilled in the tube wall through the small diameter of the ellipse, ranging in diameter from 0.025 in. to 0.062 in. produce proper dispersion of fuel in the air stream. The tubes are welded or Nicrobrazed, a process using a high melting temperature nickel-boron brazing alloy in a hydrogen atmosphere furnace, to a central manifolding system.

The service conditions imposed upon fuel spray bars are the exact opposite of those of any other component of the afterburner. When the afterburner is not operating, the turbine exhaust temperature keeps the fuel spray bars at 1200-1400 F. The moment fuel is introduced into the afterburner, the wall temperature of the fuel spray bars drops to 100 or 200 F. This condition of thermal shock must be considered when the bars are designed, especially at the junction of the bar and fuel manifold.

Exit nozzles

Segmental iris type nozzles—The segmental, iris type exit nozzle has been a fundamental advance in afterburner design. A variable type nozzle is required to provide optimum exit area for operation of the turbojet alone and of the turbojet and afterburner in combination. When the afterburner is operating, exit area must be greater than when the turbojet is operating alone.



Most of early afterburners *had an eyelid type of exit nozzle and many high production afterburners still use this type.* *(Marquardt Aircraft Co.)*

The segments of an afterburner nozzle must be capable of withstanding high operating temperatures of 1800 to 1900 F with local hot spots reaching 2000 F, of resisting oxidation by hot combustion gases, and of withstanding loads that can warp the individual segments out of line and thereby affect operation of the nozzle as a whole.

The segments are investment castings of type 310 stainless steel which is used primarily because of its high scaling resistance. They are hinged at one end and fit into a hinge ring that is connected to the combustion chamber. The segments are operated by action of a shroud that moves fore and aft along the outside of the combustion chamber, pivoting the segments from the hinge ring into a smaller or larger diameter exit area.

At one stage in the development of these segments, the edge of each segment overlapped that of its neighbor to prevent pressure loss through the nozzle. The differential temperatures set up by this configuration caused warping and cracking of the overlapped edge. The latest designs do not overlap the segments themselves. Instead, an overlapping sheet metal section of L-605 alloy is placed between each segment to prevent leakage. The L-605 is ceramic coated to prevent galling and to reduce scaling due to high service temperatures and direct combustion gas impingement.

Eyelid type nozzles—Most earlier afterburners had a clam shell or eyelid type of sheet metal exit nozzle constructed from N-155 or a similar material. Many high production afterburners of today still use the eyelid type nozzle. In the open or afterburning position, the nozzle is at 1800-1900 F. In the closed position, the nozzle is at turbine exhaust temperature, 1200-1400 F. The eyelids rotate on bearings that have been moved far enough away from the high temperature area to function reliably.

Under operating conditions, the nozzle tends to open. To prevent this, a comparatively heavy box type structure must be built on the side of the nozzle components away from the flame to keep them round. This structure is costly in weight, fabrication time, and functional design considerations. For these reasons, the eyelid type nozzle is being replaced in newer designs by the segmental, iris type nozzles.

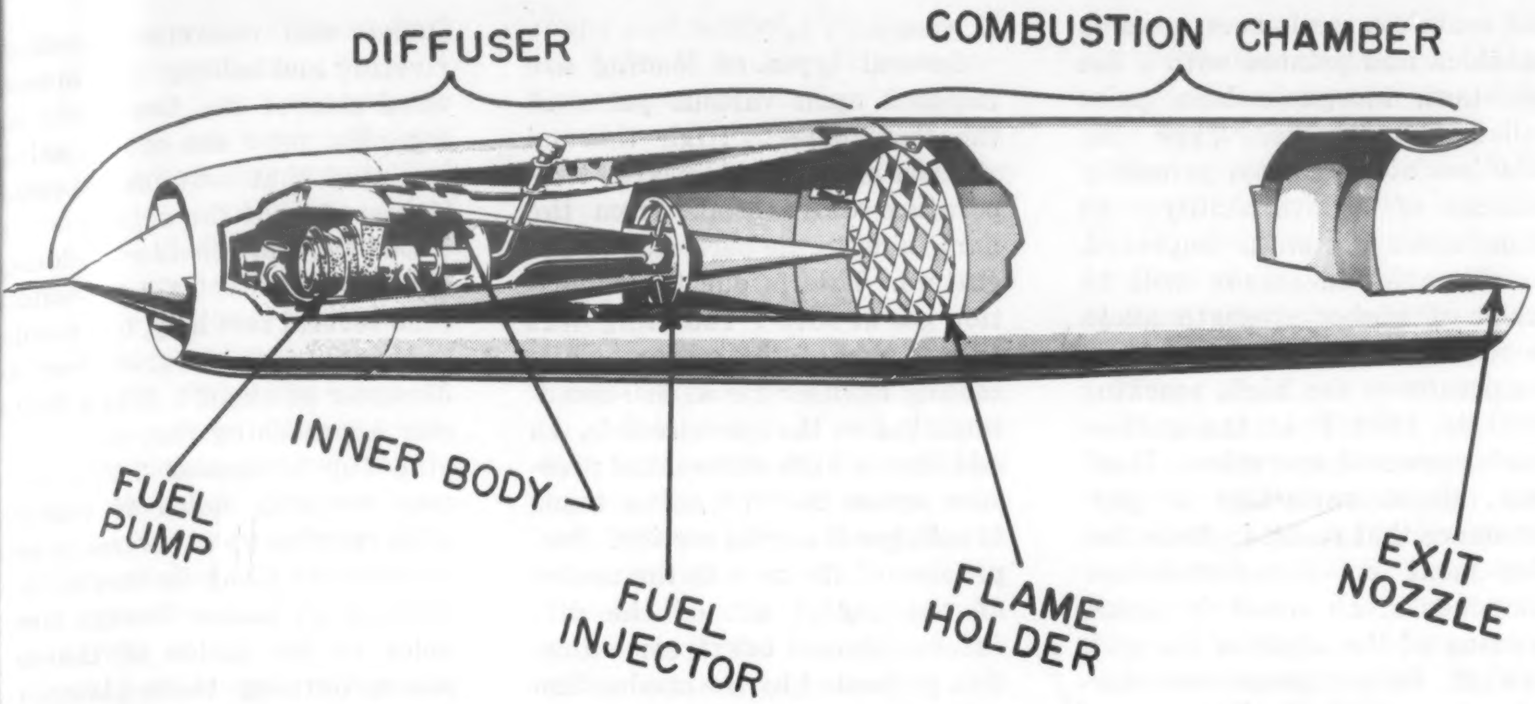
Applications in Ramjet Engines

Method of operation

A ramjet engine is an air-breathing jet engine that contains essentially no moving parts. The operating principle is like that of any other air-breathing jet engine; i.e. compress the air, introduce fuel into the compressed air, burn the mixture and exhaust the combustion gases in a manner that produces a net forward thrust reaction. Actually, the ramjet can be compared roughly with a turbojet engine as follows:

The ramjet engine depends upon its forward motion and the configuration of its inlet or diffuser to compress the incoming air. In a turbojet a compressor is required. The compressed air is driven back into the fuel injector area and fuel is sprayed into it. Then the fuel-air mixture enters the combustion chamber where combustion occurs. The combustion chamber corresponds to the combustion chambers in a turbojet engine. The hot combustion gases are then exhausted through the exit nozzle.

The differences are these: Since the ramjet does not require a compressor, a turbine to drive the compressor is unnecessary and a compressor drive shaft is eliminated. Thus, a single large diameter combustion chamber can be used instead of several small combustion cans surrounding the shaft. Therefore, all that is left in the ramjet in common with the turbojet is an inlet, a fuel injec-



A ramjet engine *is an air-breathing jet that contains no moving parts.* *(Marquardt Aircraft Co.)*

tor and a combustion chamber. In addition, there is a flameholder mechanism in a ramjet which creates a turbulence in the air stream within the combustion chamber such that it will support combustion.

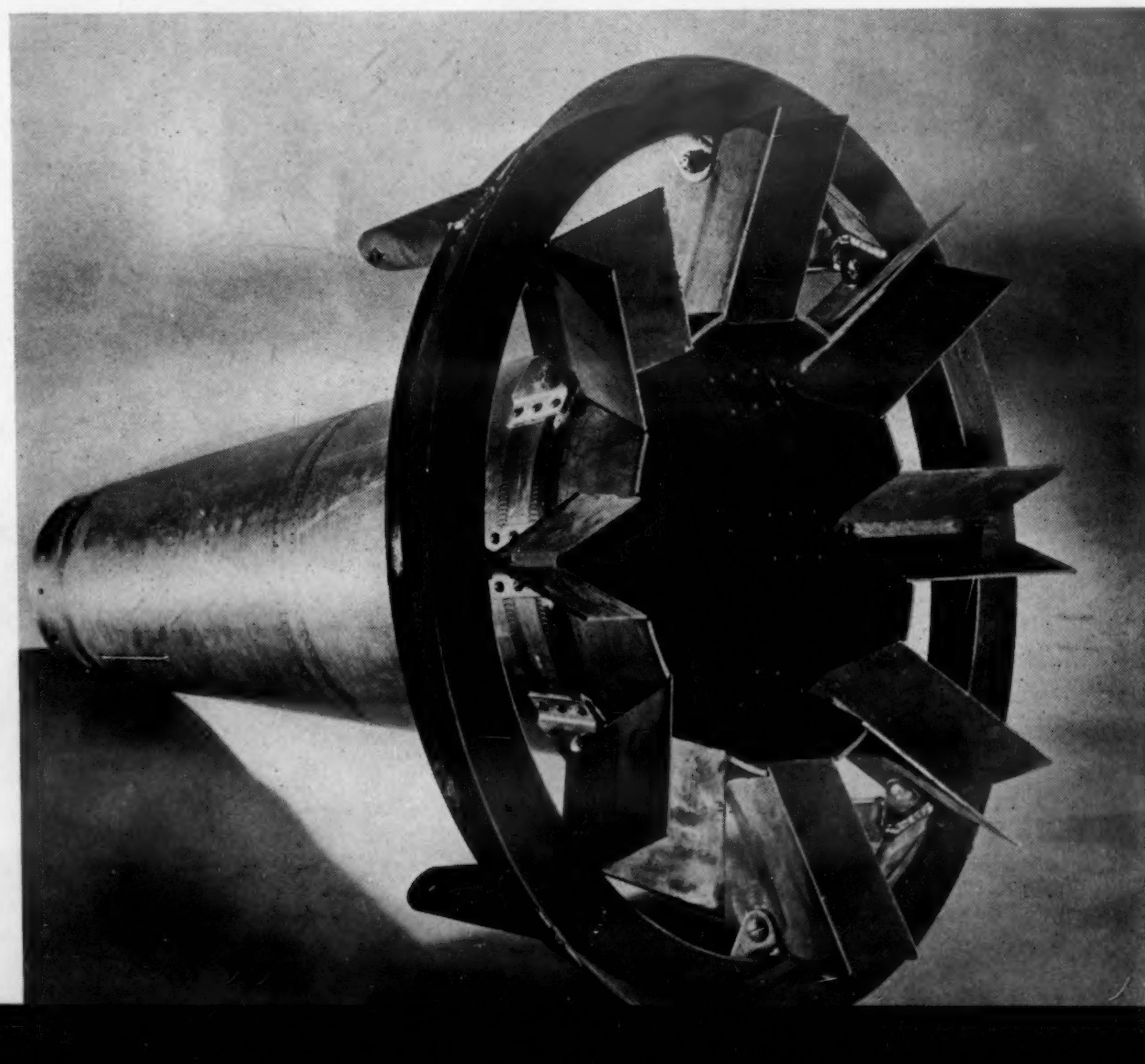
The ramjet engine cannot produce static thrust. The principle of compression by ramming air into the engine requires that some mechanism be used to get the vehicle moving through the air at speeds sufficient for it to sustain burning with usable thrust. For optimum engine performance, the versatility of this type of propulsion system is limited to a specific range of speeds and altitudes for which it has been designed. Ramjet propulsion is used in the guided missile field where rocket boost is usually used to accelerate the vehicle initially. In the field of guided missile power plants, the ramjet engine provides the most economical means of propulsion to several types of missiles for intermediate Mach numbers and altitudes. It occupies a niche all its own between the capabilities and limitations of turbojets on the low speed and altitude side, and rockets on the high speed and altitude side. It is particularly suited for single shot missile applications because of its constructional simplicity and low fabrication costs. Its thrust to weight ratio of approximately 20 to 1 is also a salient feature.

Flameholders

The only components of ramjet engines that operate at service temperatures in excess of 1200 F are the flameholder, the combustion chamber and the exit nozzle. The flameholders may be of two types of gutter or can.

Gutter type flameholder—The gutter type flameholders consist of radial and/or annular "V" shape gutters fabricated from

Gutter-type flameholders *are fabricated from sheet metal. At forward side of flameholder is a conical pilot can, which contains ignition system of the engine.* *(Marquardt Aircraft Co.)*



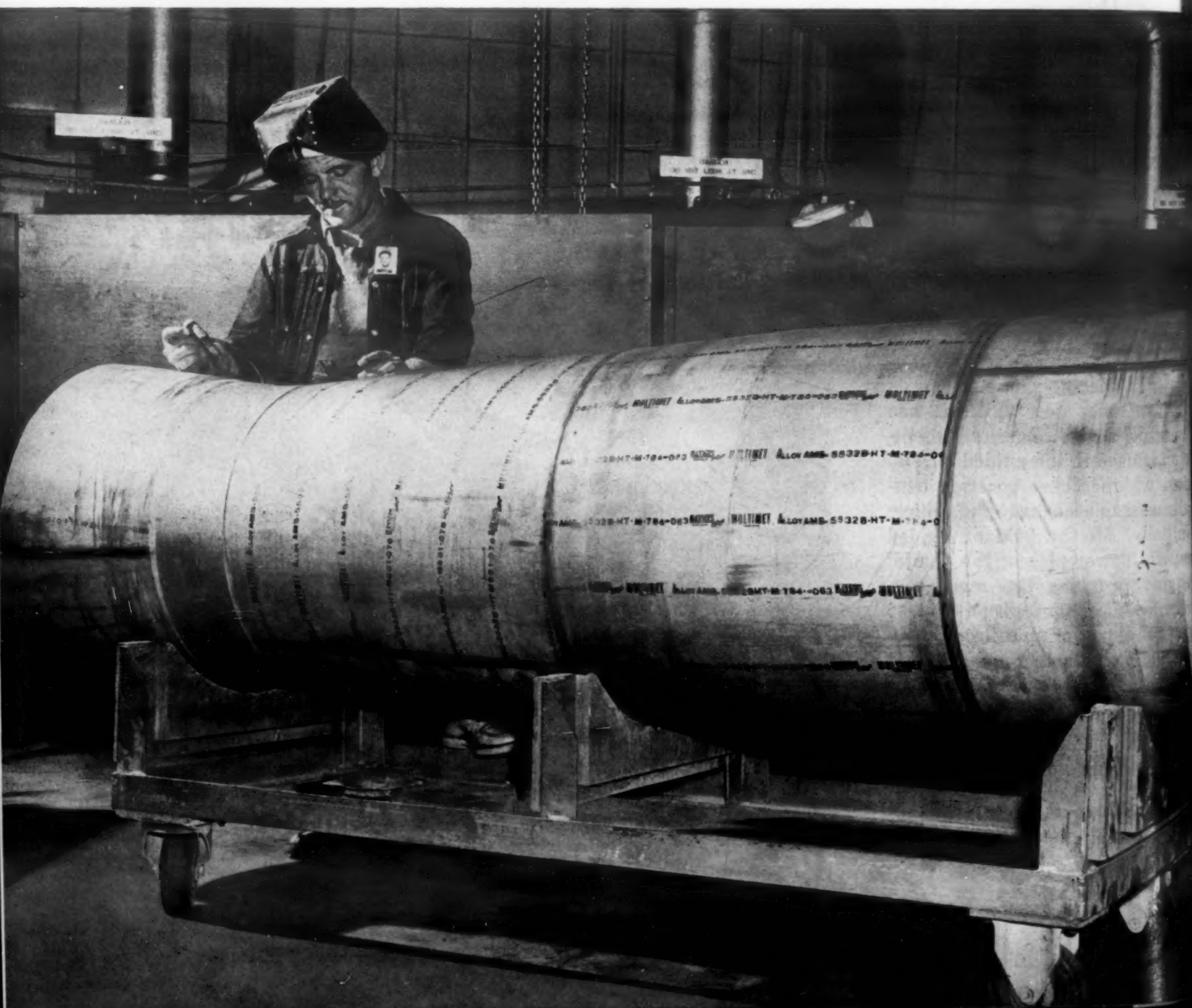
321 stainless steel sheet up to ⅛ in. thick and painted with a fire resistant, inorganic base paint called Pyrochrome. Type 321 stainless steel is used primarily because of its availability. As flameholder design is improved, considerable advantage will be taken of higher strength alloys to reduce weight. The operating temperatures are high, reaching 1800 to 1900 F at the gutters during normal operation. However, slight variations in performance that result in flame impingement on the flameholder components can result in actual burning of the edges of the gutters at temperatures considerably above 2000 F. This occurrence is not detrimental to the functioning of the engine as it is a momentary action if and when it occurs.

Several types of loading are imposed upon various parts of the flameholder. High thermal stresses are induced by large temperature differentials from the flame side to the back side of the gutters. This is due to combustion gas at 3500 F radiating heat to one side of the gutters while cooling diffuser air at 600-800 F impinges on the opposite side. In addition, a high differential pressure across the "V" gutter tends to collapse the cross section. Suspension of the unit in the center of the engine aft of the diffuser exposes it to extreme vibration generated by the combustion process.

The gutter type flameholders are fabricated from sheet metal formed into shape and joined by fusion and resistance welding, riveting and bolting. At the forward side of the flameholder is a conical pilot can of 321 stainless steel that contains the ignition system of the engine.

Can type flameholder—The can type flameholder is a truncated cone several feet long, in a standard engine, that varies from a diameter of about 1 ft to a diameter approaching that of the engine (up to approx 3 ft). The cone contains holes of various sizes ranging up to several inches in diameter along its length. The diffused air passes through these holes to the inside of the can where burning takes place. At the small diameter (upstream) end of the can, the pilot can containing the ignition system is attached. The pilot can may be a

A ramjet combustion chamber *is essentially a thin wall pressure vessel subject to varying pressures and cantilever loads that create large vibrations and fluctuations of skin material.* *(Marquardt Aircraft Co.)*



truncated cone or a cylinder with a semi-spherical head.

High operating temperatures of both pilot can and perforated main can, which may exceed 2000 F in service, necessitate use of a material resistant to scaling. For this application, type 310 stainless steel and Hastelloy X have been considered because of their high chromium content. Service loads on the can are collapsing loads for which the conical shape of the can provides maximum resistance while the high modulus of elasticity of these materials also helps resist these loads.

In the hotter areas of the can, 0.125-in. thick material is used to resist collapsing. Holes are punched in the sheet metal before it is rolled into a conical shape and welded. Finishing of the holes is an important operation. Improper hole finishing may result in elevated temperature radial fatigue cracks. The cans are painted with Pyrochrome paint to reduce oxidation.

Combustion chamber

The combustion chamber of a ramjet engine is a cantilevered, large diameter, thin wall cylinder that protrudes aft several feet beyond its junction point with the diffuser. This chamber, the integral exit nozzle, and the flameholder account for approximately half the weight of the entire engine and compose the combustion temperature limiting components in ramjet engines. The chamber is, essentially, a thin wall pressure vessel that is subject to varying pressures and cantilever loads that create large vibrations and fluctuations of the skin material.

The chamber is fabricated from 0.050-in. to 0.078-in. thick N-155 alloy into cylinders as large as 35 in. in diameter and 8 ft long. The exit nozzle portion of the chamber is formed from 0.078-in. sheet and is an integral, unfaired portion of the chamber. The service temperatures reach 1850 to 1950 F, although local hot spots and the area at the nozzle throat reach short time temperatures up to 2200 F. The forward section where the chamber is bolted to the diffuser reaches temperatures of about 1000 to 1200 F.

Fabrication of the chamber involves rolling and welding of cyl-

Inspection of tailcones *produced by welding high temperature sheet metal.* *(General Electric Co.)*

inders and cones. The contoured sections forming the nozzle area are made on an expanding mandrel. Welds are a critical part of the assembly and are made by the inert-gas-shielded arc process with no filler rod. The completed joint is roll leveled to produce a flush joint that will stand up at the high operating temperatures. The outside surface of the chamber is treated in a molten sodium dichromate bath to produce a black coating having high surface emissivity. No protection is given to the inside surface of the chamber. A spot welded doubler is located at the throat of the chamber to strengthen the hottest part of the unit and stabilize the fluctuation of the exit section during operation.

Carbide precipitation characteristics of the N-155 alloy used in the combustion chamber are an excellent indication of top temperatures reached by the metal in a particular area of the chamber. This tool has been very valuable in failure analysis during development. Between the temperatures of 1800 and 2300 F and for the service times involved in ramjet engines (of the order of several minutes), a precipitation of carbide occurs in the grain boundaries of N-155 that will pinpoint the temperature within 25 to 50 F.

The chamber is cooled by the flow of cool air along the outside surface in flight and by radiation of heat from the outside surface. For these reasons, the change in section near the throat cannot be made too severe or air layer separation will occur and the convective cooling will be lost. Radiation cooling is enhanced by the black, high emissivity coating on the outside surface.

Applications in Rockets

Metals are used in three types of rockets at service temperatures from 1000 F to just below the melting point. These are: liquid propellant rockets whose service life is 0 to 4 sec, solid propellant rockets, and regeneratively cooled rockets with service lives of many seconds to a minute and over. Uncooled rockets with intermediate service lives make use of ceramic materials to withstand the combustion temperatures. The rocket components which operate at elevated temperatures are the combustion chamber liner and the exit nozzle.

Uncooled liquid propellant rockets

Mild steel and 4130 alloy steel are used for the combustion chamber area of short life rockets such as the 0 to 4 sec uncooled liquid propellant rockets. The rate of deterioration of these materials is calculated to be slow enough for the rocket life. The chambers are rolled plate that is welded and machined to form. The steel is painted to prevent rusting prior to service. Alloy or mild steels are used in these applications rather than high temperature alloys primarily because the combustion temperature in rocket engines is so much higher than the melting temperatures of all constructional metals that the use of any metal is strictly a function of amount of deterioration in the service life.

Regeneratively cooled rockets

Rocket engines that operate for periods of the order of a minute require some method of drastically cooling the walls of the chamber in which the combustion reaction occurs. Even ceramic materials will deteriorate excessively under the operating conditions if uncooled. Therefore, double wall rocket chambers are fabricated by one of several methods and the rocket fuel is passed through the area between the walls to cool the inner wall before it is introduced into the combustion chamber.

Typical construction consists of an inner liner wall of 1/8 in. "A" nickel, mild steel or 4130 steel and an exit nozzle wall of 3/16 in. of the same materials. The cooling action keeps liner and nozzle wall surfaces between 1200 and 1500 F for the expected service life. Again, the tendency is to use a high conductivity material or low alloy steel rather than a high temperature alloy. It is also apparent that the weight of a unit area of wall is not as critical as it is in afterburners and ramjets where 0.050-in. to 0.070-in. thick combustion chamber materials must be used to reduce weight. The relative size is an important factor here. Rockets are usually smaller in diameter and length than are afterburners and ramjets.

Solid propellant rockets

This type of rocket is usually of short burning duration and is so designed that the fuel is burned from the center out to the liner wall, thus keeping the wall as cool as possible. Typical solid propellant liners and exit nozzles are rolled or forged cylinders of mild steel or 4130 machined to shape. Fiber glass laminates have also been used in a short time application.

MATERIALS ENGINEERING FILE FACTS

MATERIALS & METHODS · APRIL 1955 · NUMBER 294

Melting Points of Metals and Their Oxides*

METAL	MELTING POINT C	MELTING POINT F	OXIDE SYMBOL	MELTING POINT C	MELTING POINT F	REMARKS
Aluminum	660	1220	γ-Al_2O_3	2020	3668	—
Antimony	630.5	1175	β-Sb_2O_3	655	1221	st. >1058 F
Barium	710	1310	BaO	1920	3488	—
Beryllium	1283	2341	BeO	2520	4568	—
Bismuth	271.3	520.3	β-Bi_2O_3	817	1503	st. >1310 F
Boron	~2150	~3902	B_2O_3	577	1071	—
Cadmium	321	610	—	—	—	—
Calcium	850	1562	CaO	2570	4658	—
			CaO_2	d 400	d 752	
Carbon	3700	6692	—	—	—	Graphite
Cerium	~793	~1460	CeO_2	1950	3542	CeO_2 d 4172 F
Cesium	29.8	85.6	Cs_2O	490	914	—
			Cs_2O_2	594	1101	Cs_2O_2 d 1760 F
Chromium	~1870	~3398	Cr_2O_3	2440	4424	—
			CrO_2	d 435	d 815	—
			CrO_3	187	369	CrO_3 d 482 F
Cobalt	1495	2723	CoO	1810	3290	—
			Co_3O_4	d 910	d 1670	—
Columbium	2415	4379	γ-Cb_2O_3	1460	2660	st. >2192 F
Copper	1083	1981	Cu_2O	1230	2246	—
			CuO	d 1030	d 1886	—
Gallium	30	86	β-Ga_2O_3	1725	3137	—
Germanium	959	1758	β-GeO_2	1115	2039	st. >1891 F
Gold	1063	1945	—	—	—	—
Hafnium	~2053	~3727	HfO_2	~2900	~5252	st. <3092 F
Indium	157	315	In_2O_3	>2000	>3632	—
Iridium	2454	4449	IrO_2	d 990	d 1814	—
Iron	1539	2802	FeO	1371	2500	—
			Fe_3O_4	1457	2655	—
Lanthanum	835	1535	La_2O_3	2320	4208	—
Lead	327	621	β-PbO	885	1625	PbO-st.>986 F
			Pb_3O_4	d 530	d 986	—
			PbO_2	d 315	d 599	—
Lithium	180	356	Li_2O_2	d 160	d 320	—
Magnesium	650	1202	MgO	2800	5072	—
			MgO_2	d 50	d 122	—
Manganese	1245	2273	MnO	1790	3254	—
			β-Mn_3O_4	1580	2876	st. >2138 F
			γ-Mn_2O_3	d 940	d 1724	—
			γ-MnO_2	d 510	d 950	—
Mercury	−38.7	−37.7	HgO	d 430	d 806	—
Molybdenum	2622	4752	$MoO_{2.88}$	d 750	d 1382	—
			MoO_3	795	1463	—

METAL	MELTING POINT C	MELTING POINT F	OXIDE SYMBOL	MELTING POINT C	MELTING POINT F	REMARKS
Nickel	1455	2651	NiO	1960	3560	—
Osmium	~2700	~4892	OsO_2	~d650	~d1202	—
			OsO_4	42	108	—
Palladium	1552	2826	PdO	d 790	d 1454	—
Platinum	1773.5	3224	—	—	—	—
Potassium	63.5	146	K_2O_2	490	914	—
			β-KO_2	380	716	st. >169 F
Rhenium	3130	5666	Re_2O_7	296	565	—
Rhodium	1966	3571	Rh_2O	d 1030	d 1886	—
			RhO	d 1020	d 1868	—
			Rh_2O_3	d 990	d 1814	—
Rubidium	38.7	102	Rb_2O_2	570	1058	—
			Rb_4O_6	490	914	—
			RbO_2	412	774	—
Ruthenium	~2500	~4532	RuO_2	d 1000	d 1832	—
			RuO_4	27	81	—
Silicon	1440	2624	β-quartz	1610	2930	st. 1067-1598 F
			β-cristobalite	1713	3115	—
Silver	960.5	1769	Ag_2O	d 145	d 293	—
Sodium	97.8	208	—	—	—	—
Strontium	770	1418	SrO	2450	4442	—
			SrO_2	d 170	d 338	—
Tantalum	2996	5425	Ta_2O_5	>1900	>3452	—
Tellurium	452	846	—	—	—	—
Thallium	303	577	TlO_2	d 490	d 914	—
			Tl_2O_3	715	1319	—
Thorium	~1840	~3344	ThO_2	2950	5342	—
Tin	231.9	449.4	SnO	~1040	~1904	—
			Sn_3O_4	d 1100	d 2012	—
Titanium	~1690	~3074	β-TiO	2020	3668	st. >1814 F
			β-Ti_2O_3	2130	3866	st. >392 F
			TiO_2	1860	3380	—
Tungsten	3410	6170	WO_2	1580	2876	—
			β-WO_3	1470	2678	—
Uranium	1133	2071	UO_2	2700	4892	—
Vanadium	1900	3452	VO	2050	3722	—
			VO_2	1350	2462	—
			$V_{12}O_{26}$	670	1238	—
			V_2O_5	660	1220	—
			V_2O_3	>2000	>3632	—
Zinc	419.5	787.1	ZnO	—	—	—
Zirconium	~1830	~3325	β-ZrO_2	2715	4919	—

SYMBOLS: st.—stable.
d —decomposes.

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**NOTE: Because of a number of errors discovered in File Fact No. 294 after its publication in Feb. 1955, we are publishing it again in its entirety. The errors were inadvertently made by the editors and not by the author.*

◄ For more information, Circle No. 509

Machinability of Stainless Steels

Stainless steels are divided into three sub-groups based upon their chromium and nickel content. The ferritic and martensitic steels have similar machinability. The austenitic grades are more difficult to machine due to their tendency to cold work.

These corrosion and heat resistant steels have basically the same machining characteristics as low carbon steels with the exception that they have a higher unit shear and lower rate of heat conductivity.

Rigidity of the work and tooling is important. A soluble coolant should be used to dissipate excessive heat. The cutting edge of the tool should be honed to minimize tool build-up.

Best machinability is obtained when the ferritic and martensitic steels are cold-drawn. Soft, annealed bars will tend to tear and drag during the machining. The high ductility of annealed steels lowers their machinability. Cast alloys normally have lower machinability than do the wrought steels. They are less uniform in hardness and microstructure than are wrought steels.

Tool Angles

Type Steel	Back Rake	Side Rake	Clearance	Side Cutting Angle	Front Cutting Angle	Grade Carbide
Martensitic	0	6- 9	6	10-15	9	K2S KM
Ferritic	0	6- 9	6	10-15	9	K2S KM
Austenitic	0	9-15	10	15	9	K6

Machinability Ratings

Type	Carbon	Chromium	Nickel	Machinability
Ferritic—Straight Chromium 180–220 BHN				
405	.08	11.0-13.0	—	55
406	.15	12.0-14.0	—	50
430	.12	14.0-18.0	—	50
442	.20	18.0-23.0	—	60
443	.20	18.0-23.0	—	60
446	.35	23.0-27.0	—	65
430-F	.12	14.0-18.0	—	90
Martensitic—Heat Treatable 180–260 BHN				
403	.15	11.0-13.0	—	50
410	.15	11.0-13.0	—	50
414	.15	11.0-13.0	1.25-2.50	60
416	.15	12.0-14.0	—	85
420	.18	12.0-14.0	—	50
420-F	.18	12.0-14.0	—	70
431	.20	15.0-17.0	—	54
440	.60	16.0-18.0	—	40
501	.10	4.0-6.0	—	70
502	.10	4.0-6.0	—	70
Austenitic—Chromium Nickel 160–200 BHN				
302	.08	17.0-19.0	8.0-10.0	35
303	.15	17.0-19.0	8.0-10.0	60
304	.08	18.0-19.0	8.0-11.0	45
309	.20	22.0-24.0	12.0-15.0	48
316	.10	16.0-18.0	10.0-14.0	46
317	.10	18.0-20.0	11.0-14.0	45
321	.08	17.0-19.0	8.0-11.0	50
347	.08	17.0-19.0	9.0-12.0	48

Based upon B-1112 = 100%.
Machining index derived from unit shear energy required to form a chip.

Courtesy of the Monarch Machine Tool Co.

Application Rating

APPLICATION	High Physical Properties	Low Specific Gravity	Chemical Resistance	Ease of Fabrication	Electrical Properties
Radome	3	3	1	1	3
Boat	2	2	3	2	—
Outdoor Furniture	1	—	2	2	—
Lamp Shade	—	—	—	—	—
Tote Box	2	2	—	—	—
Auto Body[a]	2	2	—	2	—
Corrosion Test Panel	2	1	3	—	—
Pipe	2	1	3	—	—
Fish Rod	3	1	2	2	—
Food Tray	1	1	2	—	—
Washing Machine Tub	2	—	2	2	—
Truck Tank	2	2	2	—	—
Gas Meter Cover	1	—	2	—	—
Radar Scanner	2	2	—	2	—
Safety Hat	2	3	—	2	—
Aircraft Duct	2	2	—	3	—
Case or Housing[b]	2	2	?	?	—
Electrical Flat Sheet	2	—	2	—	3
Aircraft Fuel Cell Liner	2	2	—	—	—

[a] *The total takes into account a negative value of −1 (paint).*
[b] *Requirements vary depending on the particular application, but it is believed that strength, light weight and at least one additional characteristic (of those designated by ?) are desirable in most cases. Total weighted accordingly.*

Is It a Job for Reinforced Plastics?

Here is a methods that may help you recognize sound applications for these new materials.

by Robert W. Matlock, *Zenith Plastics Co.*

■ The above table represents a quantitative method of determining whether reinforced plastics should be seriously considered for a new product.

Across the top of the table are listed the important characteristics offered by glass-reinforced polyester laminates. Down the left side of the table are listed some of the most important current applications for these materials. For each application, only those spaces which correspond to properties considered desirable for that application have been designated by a number. The number may be 1, 2 or 3, depending on how important the property is to that application; the highest value, 3, is assigned where the property is considered highly desirable or necessary. The total number of points for each application is shown at the right side of the table.

Chart

Beauty of Appearance	Low Thermal Conductivity	Total
—	—	11
—	—	9
3	1	9
3	1	4
—	—	4
—	—	5[a]
3	1	10
—	—	6
—	—	8
2	—	6
—	—	6
—	—	6
2	—	5
—	—	6
—	2	9
—	—	7
?	?	5[b]
—	—	7
—	—	4

Using the table

Roughly, then, the higher the total number of points for a specific application, the more likely it is to be a successful application for reinforced plastics.

Still more can be learned from the table, however. Note that the largest total value is 11. It seems improbable that any application could achieve more than 12 points. Similarly, the lowest value is 4, and it seems unlikely that any application could gain acceptance with less than 4 points. Since gas meter housings and cases (5 points) have yet to prove themselves good applications, even a total value of 5 points may generally be considered indicative of a marginal application. On the other hand, aircraft ducts and electrical flat sheet (both 7 points) have been highly successful applications. It seems likely that any product with 7 or more points may be an excellent application for reinforced plastics.

Consider disadvantages

Sometimes definite disadvantages of reinforced plastics must be taken into consideration. This can be done by assigning negative values. For example, in the above table a value of –1 represents the need for paint in the auto body application. If a disadvantage seems to call for a still greater negative factor, reinforced plastics are probably not suitable for the application.

The table does not include all of the factors required for a decision. For example, the maximum number of points that can be assigned to liners of aircraft self-sealing fuel-cell cavities is 4. However, reinforced plastics simply tear when pierced by a bullet, whereas metal tends to "flower" and prevent the hole in the tank from closing up again. As a result, a reinforced plastic is an excellent material for this job. On the other hand, the need to withstand a temperature of 1000 F or to have optical transparency may rule out reinforced plastics despite a high numerical rating by this system.

Also, cost is not included in the table. Reinforced plastics are not cheap materials. Generally, reinforced plastics are used because they have certain merits that, in a given application, outweigh their cost disadvantages. In some applications, usually military, performance is so important and cost so relatively unimportant that the engineer need hardly consider cost.

Other factors not included in the table are production quantities, tooling cost and simplicity, available floor space, frequency of design changes, and time between design and production.

Hence, the method of analysis described here is not a positive, infallible formula. Its only purpose is to help the design engineer recognize sound applications for reinforced plastics.

Based on the paper, "Recognizing Applications for Reinforced Plastics", presented at the annual meeting of the American Society of Mechanical Engineers in New York last December.

They heat treat 50 different types of gears . . .

with one type of THERMALLOY* TRAY

Thermalloy tray and fixtures with adapter in place to give different loading pattern. Spacers at right.

A large automotive parts manufacturer processes over 50 different types of gears in a carburizing-oil quench furnace where temperatures range to 1700°F. A heat-treat tray design was needed to withstand rugged service...to give maximum loading for all gears.

Here's how Electro-Alloys developed a versatile tray to meet these conditions:

First: Electro-Alloys engineers designed a type of tray and set of fixtures to handle this wide variety of gears. This was accomplished by supplying adapters and spacers to supplement the basic tray design. With this adaptability, fewer trays were needed . . . less handling time was required in heat treating the variety of gears.

Second: Trays, fixtures, adapters, spacers . . . all were cast in Thermalloy . . . a tough heat-resistant alloy developed specifically to take heavy loads and rough usage . . . to withstand elevated temperatures up to 2100°F. without scaling or cracking. This tray takes loads up to 315 lbs. per tray . . . has been in service for over 13 months.

Electro-Alloys has helped engineer many types of heat-treat parts and has cast them in Thermalloy for longer life. Why not put this knowledge to work for you . . . call your nearest Electro-Alloys office or write Electro-Alloys Division, 6001 Taylor Street, Elyria, Ohio, for a copy of Thermalloy Tray & Fixture Bulletin T-227.

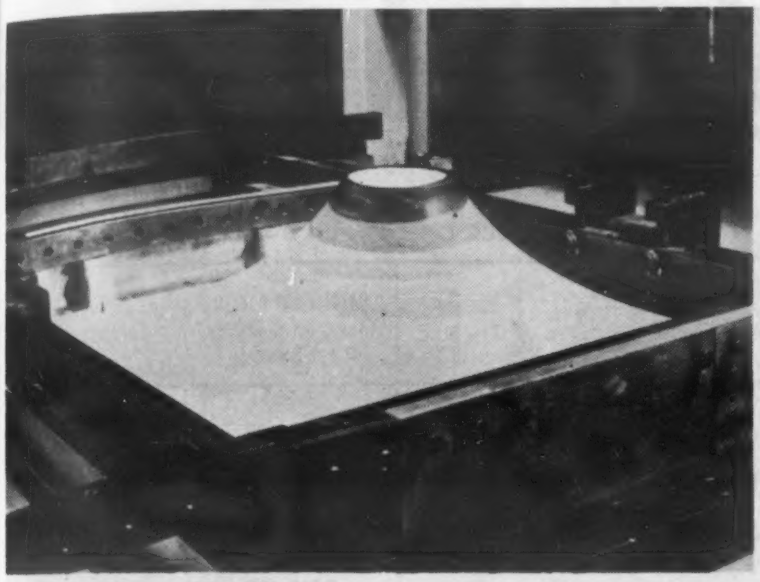
AMERICAN Brake Shoe COMPANY

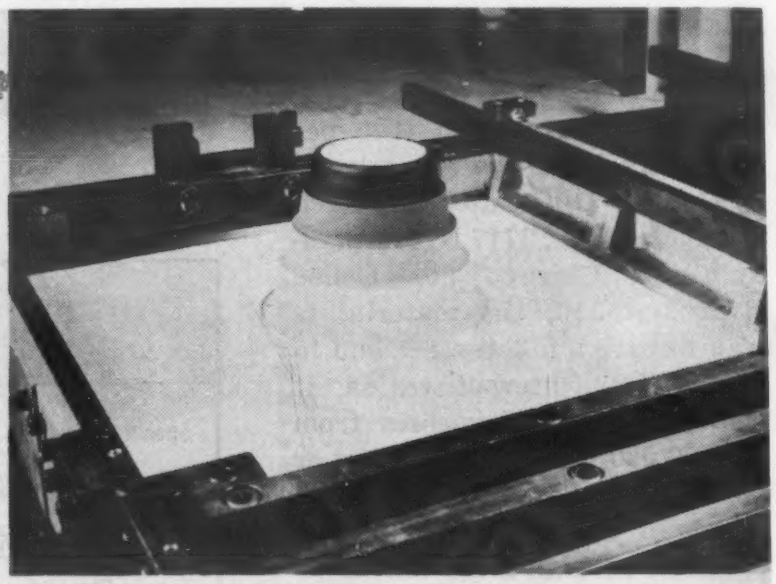
ELECTRO-ALLOYS DIVISION
Elyria, Ohio

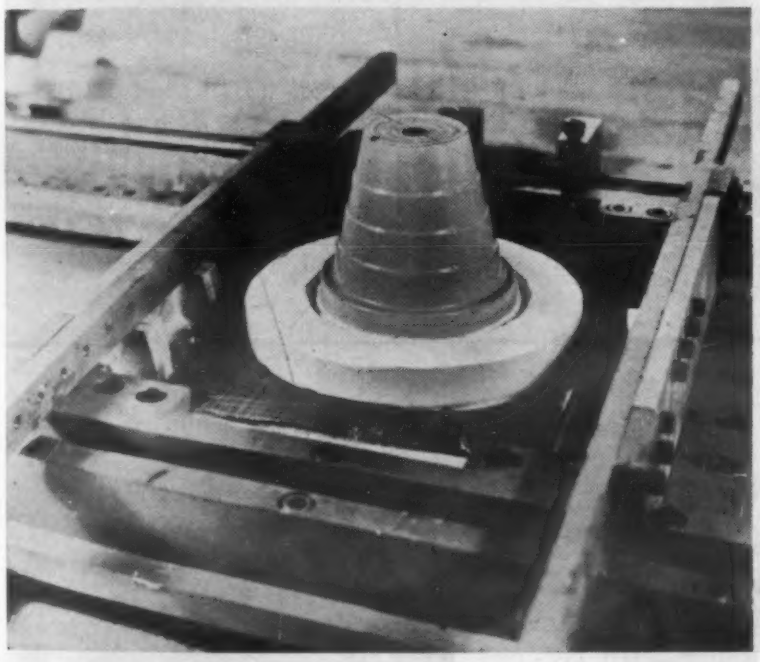
*Reg. U. S. Pat. Off.

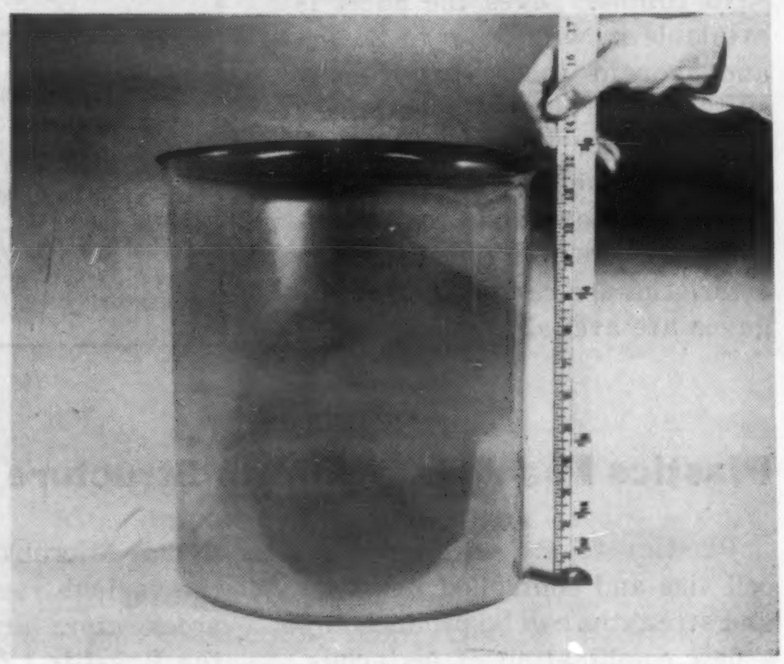
For more information, turn to Reader Service Card, Circle No. 411

New Materials, Parts and Finishes
and related equipment









***Freedom from internal strains** permits new sheet to be decorated while flat, then formed to desired shape. Improved extensibility at high temperatures permits forming of deep shapes such as can liner at lower right.*

Lower-Cost Vinyl Sheet Aids Vacuum Forming

Rigid vinyl sheet is now being calendered in thicknesses up to 0.040 in., and in widths up to 51-1/2 in. Surfaces are said to be comparable to those of press-matted sheets. The sheet offers fabrication advantages in that designs and decorative effects can be applied before forming a product. Current tests indicate light stability such that no change in light transmission values, color or other significant properties of the sheet occurs after 15,000-hr continuous exposure to fluorescent light. It is being produced in continuous or custom-cut lengths by *Bakelite Co., Div. of Union Carbide and Carbon Corp.*, 30 E. 42nd St., New York 17. Complex shapes have been formed with 8-sec preheat time, using relatively inexpensive equipment, according to the company. It is particularly suitable for parts such as deep-drawn can liners, as well as for vacuum formed three-dimensional advertising displays.

It is said to have good strength and wear resistance.

New Materials, Parts and Finishes
and related equipment

Rubber-Modified Styrene Sheet Has High Impact Strength

A rubber-modified styrene sheet said to have an Izod impact strength of 2.5 to 4.5 ft-lb per in. of notch has been marketed by *Campco Div., Chicago Molded Products Corp.,* 2717 N. Normandy Ave., Chicago 35. Called Campco S-540, the material is said to have a fine texture and to be free from internal strains. It is available in thicknesses from 0.010-0.030 in. with either mat or polished surface, and in thicknesses of 0.040-0.187 in. in mat, polished or high-gloss finish.

In thinner gages the sheet is available in widths up to 26 in., and is said to be particularly suitable for printed jobs where close register is required. It is also recommended for displays, packaging, toys and other applications where high physical characteristics are required. Heavier gages are available in widths up to 40 in. and are recommended for equipment housings, refrigerator parts, racks, trays and similar applications. An accompanying table lists typical physical properties of the sheet.

TYPICAL PROPERTIES OF CAMPCO S-540

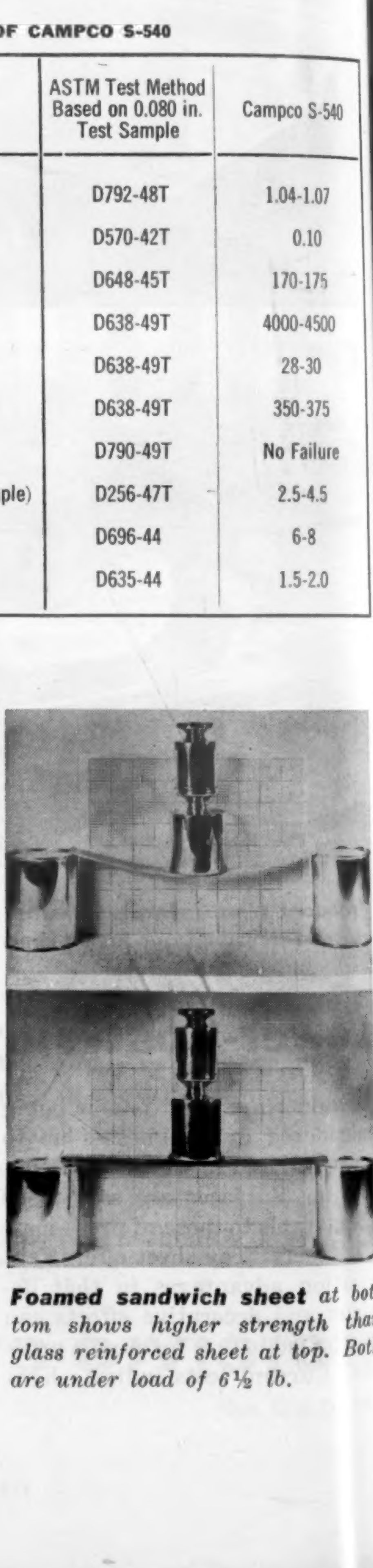
	ASTM Test Method Based on 0.080 in. Test Sample	Campco S-540
Specific Gravity	D792-48T	1.04-1.07
Water Absorption, 25 hr, %	D570-42T	0.10
Heat Distortion, F (264 psi)	D648-45T	170-175
Tensile Strength, psi	D638-49T	4000-4500
Elong in Tension, %	D638-49T	28-30
Mod in Tension, psi x 10^3	D638-49T	350-375
Flexural Strength, psi	D790-49T	No Failure
Impact Str (notched, ft lb/in. of notch. 0.060 test sample)	D256-47T	2.5-4.5
Coef of Exp x 10^{-5}/in./in./°F	D696-44	6-8
Flammability	D635-44	1.5-2.0

Plastics Foam Has Uniform Structure

Plastics foams with uniform cell size and controlled densities and strengths can be produced by a new combination of materials. Developed by *Bakelite Co., Div. of Union Carbide and Carbon Corp.,* 30 E 42nd St., New York 17, the so-called syntactic foams are made by bonding microscopic phenolic spheres (average dia, 0.0013 in.) with phenolic, epoxy or polyester resins. The tiny spheres, called Microballoons, were originally developed by the Standard Oil Co. (Ohio) and Bakelite. They can be used in varying proportions with phenolic, epoxy or polyester resins to produce cast foams or sandwich structures which have a wide range of properties.

The Microballoons as well as the various resins, catalysts and accelerators are available from the Bakelite Co. along with recommendations for use. When mixed, the material is putty-like in consistency and can be molded to shape, trowelled on suitable surfaces, forced into cavities or pressed in sandwich core structures. Properties of resulting foams indicate potential applications in airplane wing structures, casings for air conditioning units and refrigerators, plastics boats, gun stocks and other end uses where a combination of strength and light weight is required and costs must be minimized.

(More New Materials on page 144)



***Foamed sandwich sheet** at bottom shows higher strength than glass reinforced sheet at top. Both are under load of 6½ lb.*


MAKE IT WEIGH LESS
N·A·X
HIGH-TENSILE STEEL
MAKE IT LAST LONGER

New Materials, Parts and Finishes
and related equipment

Color-Fast Plastics Aid Light Transmission

Two polyester resins designed to minimize color fading and maintain favorable light transmission in structural reinforced plastics parts have been developed by *Bakelite Co., Div. of Union Carbide and Carbon Corp.*, 30 E. 42nd St., New York 17. The resin designated PLLB-5003 Natural is color stabilized and will resist color fading under direct sunlight. The other resin, PLLA-5006 Natural, is light colored also, and is recommended for those fabricators who wish to add their own light-stabilizing agent.

According to the producer, both resins wet glass reinforcing equally well and when cured have good resistance to cracking, crazing, weathering and most chemicals. They are recommended for such uses as skylights, greenhouses, factories, patio and porch roofs, outdoor partitions and decorative window panels.

Paper-Base Epoxy Laminate for Printed Circuits

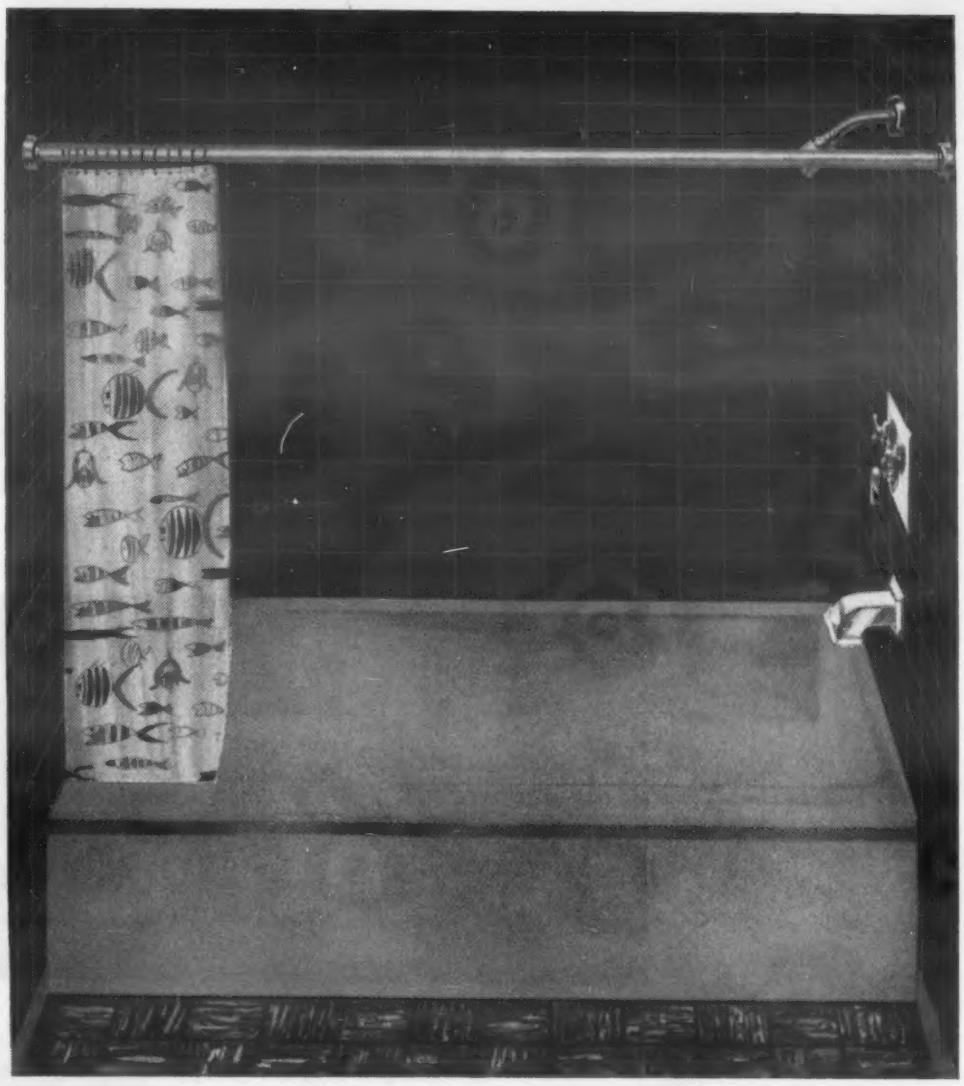
A new paper-base epoxy high pressure laminate has been developed for printed circuit manufacture by *American Printed Circuits Co., Inc.*, Forrest St., Metuchen, N.J. Available either as a straight epoxy-paper laminate or joined to 1-2 mil copper, the sheet is produced in thicknesses of 1/32 to 1/2 in., in sizes up to 18 x 18 in. Called Epinate, the material is said to incorporate the high mechanical strength, low water absorption, low thermal ex-

AVERAGE TYPICAL PROPERTIES OF EPINATE

Property	ASTM Test Method	Value
Tensile Str, psi	D638-52	—
Lengthwise	—	17,600
Crosswise	—	17,500
Mod of Elast in Tension, psi	D638-52T	—
Lengthwise	—	1.15×10^6
Crosswise	—	1.18×10^6
Flexural Str, psi	D790-49T	—
Lengthwise	—	24,600
Crosswise	—	24,800
Impact Str, ft-lb/in. notch	D256-47T	—
Lengthwise	—	0.56
Crosswise	—	0.64
Compressive Str, psi	D695-52T	—
Flatwise	—	31,400
Edgewise	—	22,200
Heat Distortion Temp, F	D648-45T	400
Rockwell Hardness	D785-51	M110
Flammability, in./min	D635-44	0.37
Coef of Lin Therm Exp per °C (−30 to 30 C)	D696-44	2.17×10^{-5}
Dissipation Factor	D150-47T	—
Dry[a]	—	0.0096
After 24-hr water immersion[b]	—	0.0633
Dry[c]	—	0.030
Dielectric Str (step by step), v/mil	D149-44	821
Surface Resistance, ohms	D257-52T	1.12×10^{15}
Arc Resistance, sec	D495-48T	93
Water Absorption, 24-hr immersion, %	D570-42	0.27
Hot Dip Test[d], F	—	420 Unaffected 440 Deteriorated

[a] *60 cycles/sec, 0.1272-in. thick specimen.*
[b] *60 cycles/sec, 0.1261-in. thick specimen.*
[c] *1 megacycle/sec, 0.0677-in. thick specimen.*
[d] *Specimen dipped for 30 sec in commercial solder at increasingly higher temp.*

Here's why Reinforced Vibrin is being used for "PLASTEX" MOBILE HOME BATH TUBS *



LIGHT IN WEIGHT—Weighs only a small fraction of ceramic or porcelain ware. Costs less to ship, less to handle. Puts less load on floors.

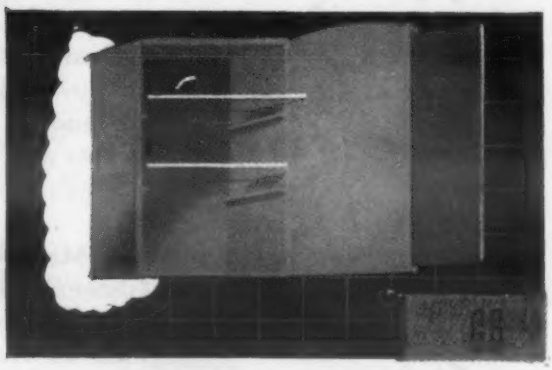
LASTINGLY BEAUTIFUL—Its high-gloss, non-porous surface is extremely durable—resists chipping, cracking, or crazing.

WARM TO THE TOUCH—Transmits heat very slowly; never feels cold; keeps water warmer, longer.

WHY NOT reinforced Vibrin for...

...*household* wash basins and tubs?

...toilet tanks and bowls?



...medicine cabinets?

VERSATILE VIBRIN® polyester, reinforced with glass fibers, yields products that are, pound-for-pound, even stronger than steel...but far less expensive to mold! They are dent-proof, rust-proof, and highly resistant to heat, abrasion and chemicals. VIBRIN can also be pigmented with a variety of attractive colors.

Consider how ideally VIBRIN lends itself to these and hundreds of other items—perhaps to some *you* manufacture!

Write Naugatuck Chemical today.

*Made by Palmer Plastics, Inc.
13120 E. Nine Mile Road,
East Detroit, Mich.

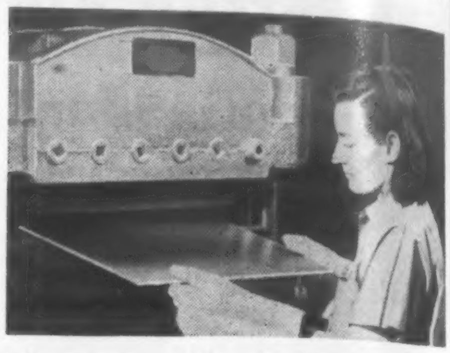
Naugatuck Chemical

Division of United States Rubber Company
Naugatuck, Connecticut

BRANCHES: Akron • Boston • Charlotte • Chicago • Los Angeles • Memphis • New York • Philadelphia • IN CANADA: Naugatuck Chemicals, Elmira, Ontario
Rubber Chemicals • Synthetic Rubber • Plastics • Agricultural Chemicals • Reclaimed Rubber • Latices • Cable Address: Rubexport, N. Y.

For more information, turn to Reader Service Card, Circle No. 310

New Materials, Parts, Finishes



pansion and high electrical properties characteristic of epoxy resins. Typical properties of Epinate shown in an accompanying table were determined by U.S. Testing Co., Inc.

Corrosion-Resistant Liquid Primer

LockPrime, a corrosion-resistant liquid primer for new or corroded steel surfaces, has been developed by *Pennsylvania Salt Mfg. Co.*, 1000 Widener Bldg., Phila., Pa. Applied by brush or roller the primer is suitable for all ferrous metal surfaces.

When used on sandblasted new steel or wirebrushed rusted steel, LockPrime is said to form a tight adherent bond to the surface and to provide a good base for top coats. As the bond strength of the primer increases with age, immediate application of a top coat is unnecessary, according to the company.

Effective in acidic and organic atmospheres, the tile-red primer contains 28% solids content by weight and covers 200 sq ft per gal per 1-mil coat. It is available in 1-gal cans and 5-gal drums.

Two Titanium Alloys Now in Quantity Production

Two titanium alloys, one a weldable alloy with high notch toughness, the other a heat treatable alloy, are now in quantity production at the *Mallory Sharon Titanium Corp.*, Niles, Ohio. Designated MST 6A1-4V, the 6 aluminum, 4% vanadium alloy is

TEMPER

is important

Specify Bishop Stainless Steel Tubing

When temper is important specify Bishop small diameter stainless steel tubing (.008" to 1" O.D.) because you can rely on Bishop to insure delivery of stainless steel tubing properly tempered for the job on hand.

Bishop, specialists in materials for corrosion resistance since 1842, takes pride in its careful craftsmanship of stainless steel tubing . . . a pride that reflects itself in meticulous control of heat treatment temperatures, times and frequency to insure you the finest tempered tubing for the end use or specifications required.

The next time, particularly if temper is important, specify Bishop and be sure. Catalog on request.

J. BISHOP & CO. PLATINUM WORKS

Stainless Steel Division • Malvern, Pennsylvania

Platinum and Platinum Group Metals
Stainless Steel Tubing
Tubular Fabricated Parts
Spinnerettes
Hypodermic Needles and Syringes

For more information, turn to Reader Service Card, Circle No. 370

New Materials, Parts, Finishes

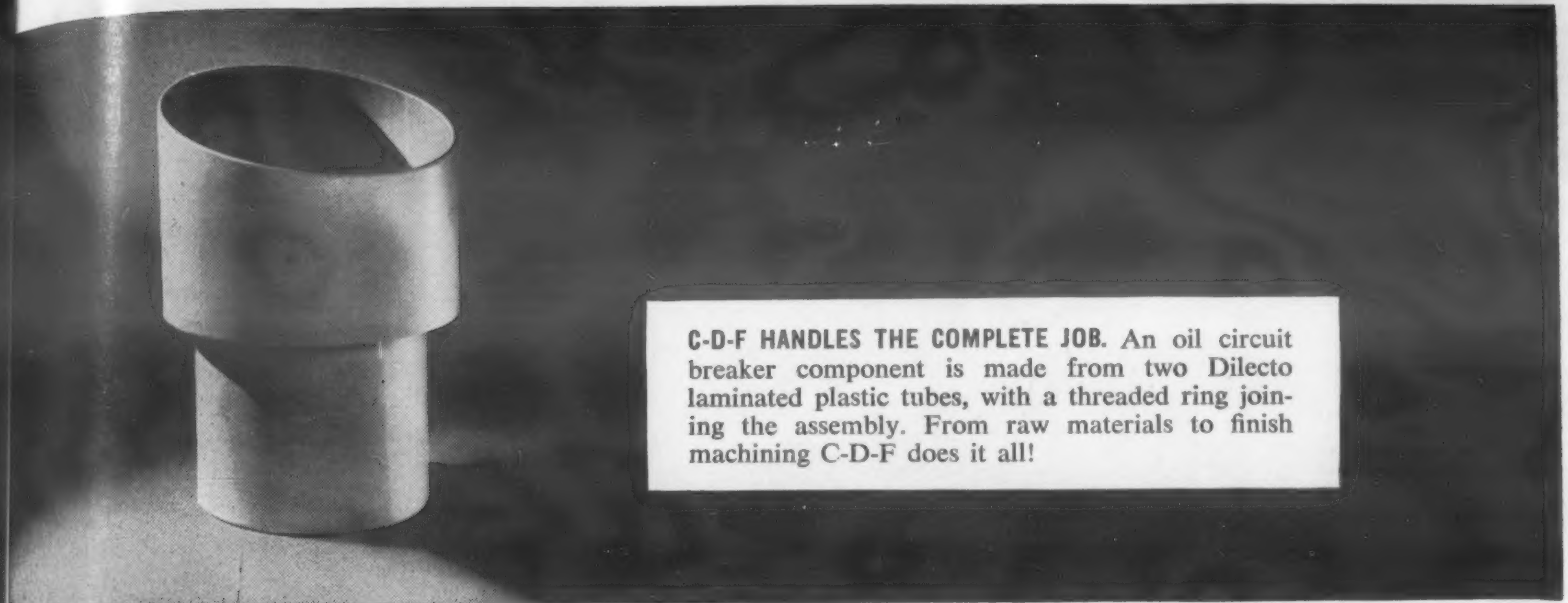
weldable, and has high notch toughness and properties comparable to those of high strength steels. Developed by Armour Research Foundation under contract to Watertown Arsenal Lab, the alloy is said to overcome brittleness present in many other commercial high-strength titanium alloys. According to the producers, it has high thermal stability and can be used at temperatures up to 750 F with maximum creep resistance.

Composed of 3 manganese, 1 chromium, 1 molybdenum, 1 vanadium, 1% iron, with balance titanium, the so-called MST 3Mn Complex alloy is made by Mallory-Sharon's "Method S", double melting using a consumable electrode. Properties of the alloy can be varied predictably by heat treatment. Also the alloy is said to meet the need for a high-strength alloy containing a minimum of strategic alloys and harmful alloying ingredients. Developed by Battelle Memorial Institute, under Air Force contract in conjunction with the Wright Air Development Center, the alloy is designed for use at temperatures up to about 500 F.

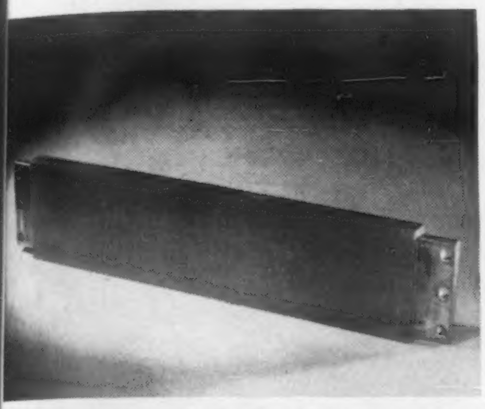
Flexible Tooling Epoxy Has High Impact Strength

A flexible epoxy casting resin, designated L-940, has been marketed for use in fabricating drop hammer punches, draw dies, pressure pads and clamping punches. According to the supplier, *Rezolin, Inc.*, 5736 W. 96th St., Los Angeles 45, in many cases the material eliminates the need for sheet metal clearance between matched dies. To form a punch, the material should be cast in thicknesses of 1/4 to 2 in. over a metal core. The female die member may be of a rigid epoxy.

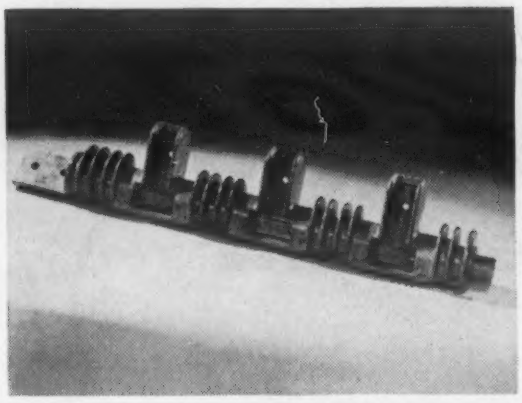
L-940 was developed to provide



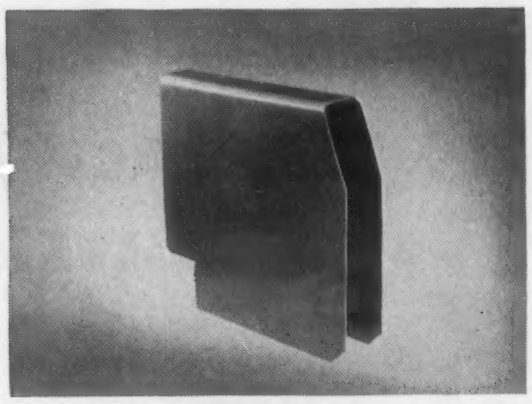
C-D-F HANDLES THE COMPLETE JOB. An oil circuit breaker component is made from two Dilecto laminated plastic tubes, with a threaded ring joining the assembly. From raw materials to finish machining C-D-F does it all!



C-D-F KNOWS HOW TO MACHINE PLASTICS. A bus bar gets a covering of molded Dilecto over copper supplied by the customer. The plastic ends are skillfully trimmed on a smooth saw.

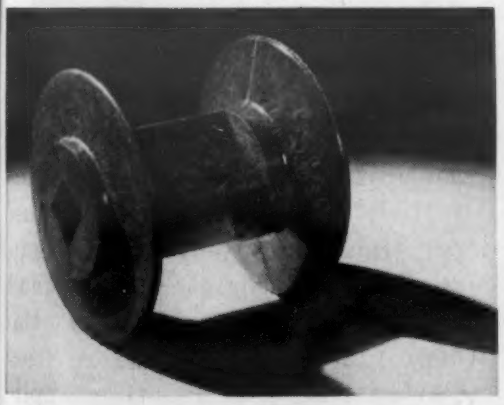


C-D-F MOLDS MANY SPECIALTIES. This shaft insulator for a circuit breaker is molded from C-D-F's cloth-based industrial thermosetting plastic, Celoron. Note complexity of mold, clean detailing.



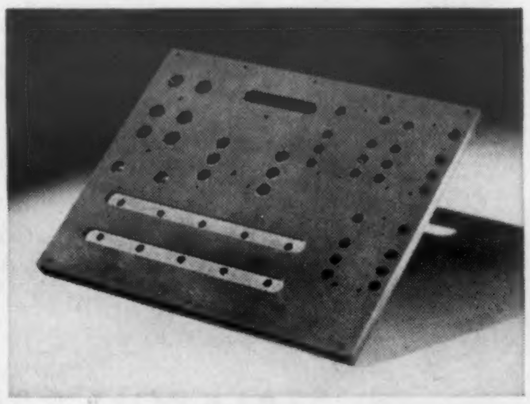
C-D-F USES MODERN METHODS. Large quantities of arc chute barriers are made from paper-based Dilecto. Operations include pressing, cutting, post-forming and trimming.

DEPENDABLE equipment RELIES on C-D-F INSULATION!



C-D-F OFFERS UNIQUE MATERIALS. This contact shaft for an air circuit breaker is another example of molded C-D-F Celoron used in switchgear because of its high impact strength.

C-D-F IS A SKILLFUL ASSEMBLER. Made from Grade C rolled Dilecto tubing, these pots are turned, bored, slotted. Then a macerated plastic end is inserted and arc resistant varnish finish applied.



C-D-F UNDERSTANDS THE ELECTRICAL INDUSTRY'S NEEDS. Precisely machined to close tolerances, Dilecto panel boards guarantee dependable insulation, help designers save space.

See our catalog in Sweet's Design File for basic product data and sales offices. Write for detailed information, or send us your print for quotation.

CDF *Continental-Diamond Fibre*

CONTINENTAL-DIAMOND FIBRE COMPANY

NEWARK 15, DELAWARE

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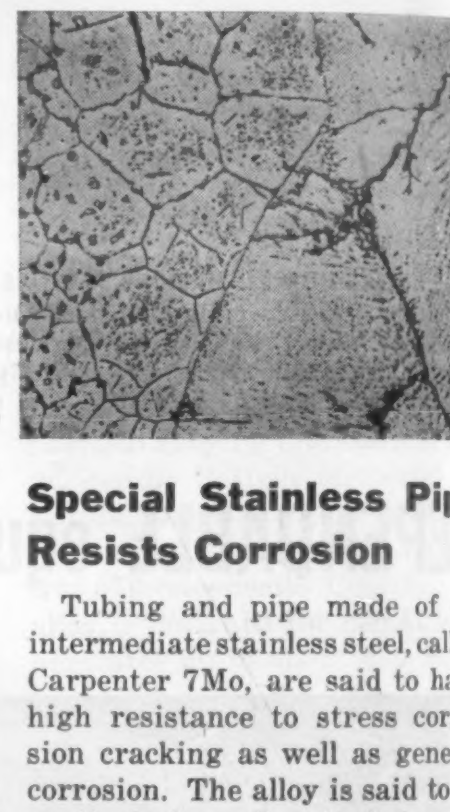
a material which would retain a predetermined flexibility over an extended period of time. Degree of flexibility can be altered by altering the proportion of Flexicizer. No special mixing equipment is required. Resin is mixed cold, cast without pressure and cured at room temperature. L-940 with 50-60 Shore D-2 is available in pre-weighed gallon units, as well as in larger units.



Special Stainless Pipe Resists Corrosion

Tubing and pipe made of an intermediate stainless steel, called Carpenter 7Mo, are said to have high resistance to stress corrosion cracking as well as general corrosion. The alloy is said to be particularly well suited for use in tubing and pipe which are subjected to chlorides, halogen ions, certain caustic solutions and acid conditions associated with food processing. According to the manufacturers, *Carpenter Steel Co.*, of Union, N.J., other applications include equipment for chemical processing, pulp manufacturing, petroleum refining and heat exchangers handling brackish water.

Nominal composition of Carpenter 7Mo is: 0.08 max carbon, 3.75-4.5 nickel, 26.5-28.0 chromium, 1.35-1.65% molybdenum, bal iron. Hardenability of the steel makes it useful where seizing or galling is a problem. Like

Keep it Clean with

Washing machines need good, tight, long-lasting seals to keep water where it belongs, oil and grease in the right places, too. Felt seals by American protect the trouble-free reputation of many products of all kinds from tractors to electric motors. It is important to select the right quality for every application. American engineers will collaborate with you on specifications.

Seals are available from American in plain felt, or laminated with one or more layers of impervious, oil-proof Hycar. Tell us what you want a seal to do and we will show you the seal that should do it.

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For more information, turn to Reader Service Card, Circle No. 353

New Materials, Parts, Finishes

austenitic steels, it is annealed by water quenching from a high temperature. But unlike austenitic steels, it precipitation hardens when soaked at a lower temperature and cooled slowly in the furnace.

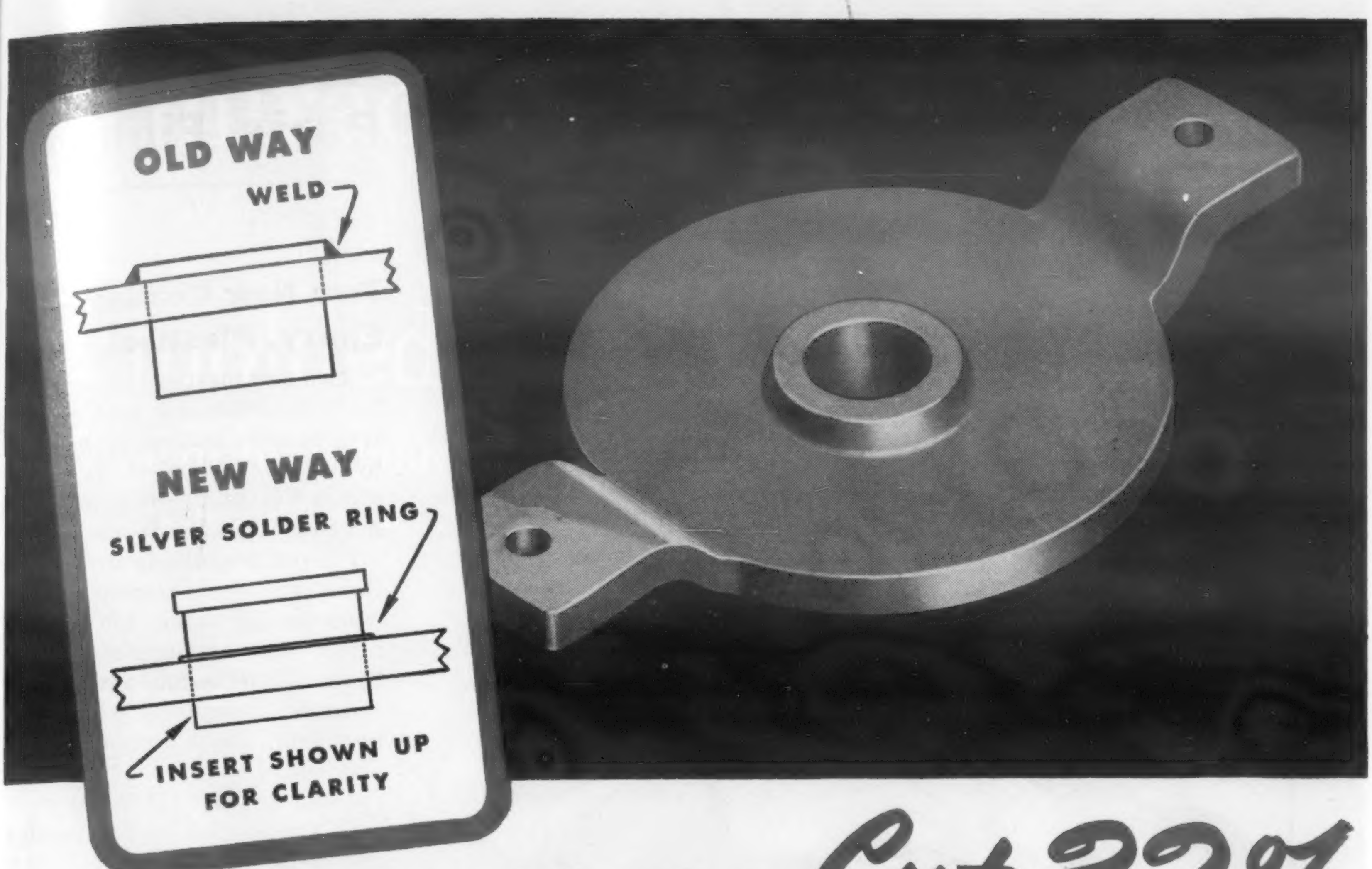
The material is reported to have considerably greater resistance to stress corrosion cracking than 18:8 austenitic grades. At the same time it is said to be more resistant to general corrosion than 12 and 18% chromium irons which also withstand stress corrosion cracking in environments where austenitic grades fail. Its resistance to general corrosion and pitting is similar to that of type 316, but in resisting stress corrosion cracking it is said to be superior.

Corrosion Protection and Insulation Combined in Spray Coating

A black spray coating made of processed coal tar pitch, mineral filler, solvent, and granulated cork is now being manufactured to protect metal equipment from corrosion. It provides a moderate degree of thermal insulation and may be used where massive insulation is not required. Needing no primer, one application of Bitumastic "K" produces a coating up to 1/2 in. in thickness.

According to the manufacturer, *Tar Products Div. of Koppers Co., Inc.*, Pittsburgh 19, the cork mastic was developed for protecting metal tanks containing heated materials from corrosion as well as major heat loss. It is said to be best suited for oil and asphalt storage tanks or any metal tank whose contents are kept at temperatures up to 150 F. Bitumastic "K" is also applicable for chemical plants or equipment, corrugated steel sidings, and heating and ventilating ducts.

(More New Materials on page 154)



Assembly Cost *Cut 32%* with TOCCO* Induction Brazing

Now's the time to balance YOUR production budget

This assembly may bear no resemblance to your product, but its case is typical of the savings accomplished by Induction Heating of metal parts of all sizes and shapes.

Formerly the Norris Thermador Corporation used arc welding to join the bushing and clamp shown above. In an effort to reduce costs TOCCO Induction Heating was brought into the production picture with the following results:

OLD METHOD (Arc Welding)		NEW METHOD (TOCCO Induction Brazing)	
Material (rod)	$ 4.56 per M parts	Material (solder and flux)	$13.83 per M parts
Labor	20.63 per M parts	Labor	8.82 per M parts
Overhead	21.25 per M parts	Overhead	9.08 per M parts
Total Cost Old Method	$46.44 per M parts	Total Cost TOCCO Method	$31.73 per M parts

TOCCO Engineers are glad to survey your operations for similar cost-cutting results—no obligation, of course.

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Please send copy of "Typical Results of TOCCO Induction Brazing and Soldering."

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Address__________
City_____ Zone___ State_____

For more information, turn to Reader Service Card, Circle No. 352

New Materials, Parts, Finishes

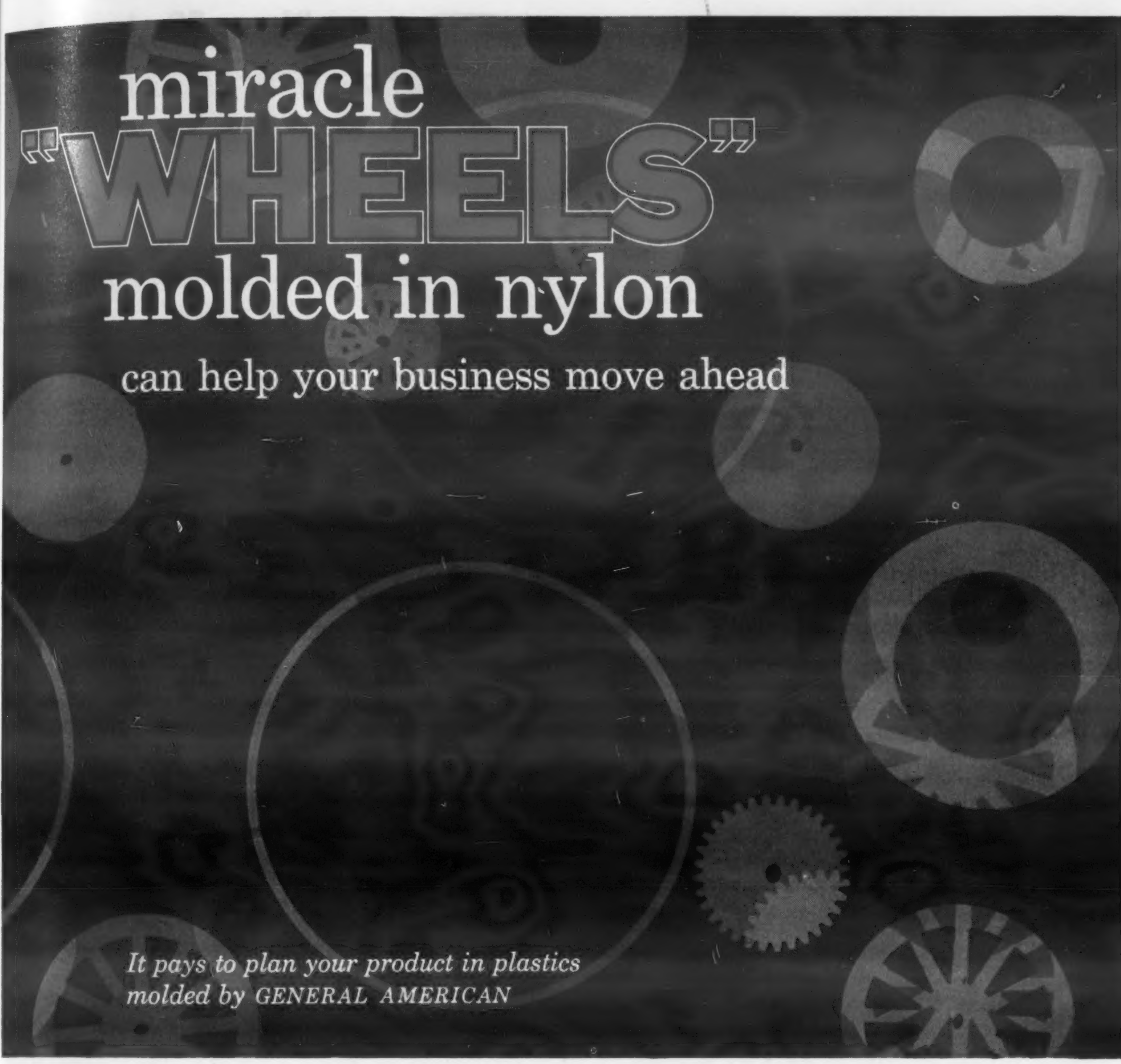
Two New Coatings—Epoxy, Plastisol

Two new plastics coatings have been marketed for both protective and decorative applications by *Dennis Chemical Co.*, 2701 Papin St., St. Louis 3, Mo. Perma-Skin epoxy coatings can be air-cured, permitting use on large items such as chemical process equipment, water towers and tanks. The coatings are said to have high adhesion, abrasion resistance, toughness, flexibility and acid, alkali and solvent resistance.

Denflex plastisol metal coatings are applied by first coating the metal surface with Denflex No. 2386 primer, by brushing, dipping or spraying. After air drying for 15 to 20 min the plastisol finish may be applied and baked. According to the company, the material may be used to produce a soft, resilient, decorative coating, or a hard, tough finish of substantial thickness. Gloss and color can be supplied as desired. Resulting coatings are said to have high resistance to weathering, abrasion and corrosion. They are also said to be suitable for use as electrical insulation. Suggested uses include tool handles, tank linings, outdoor furniture, and air conditioner cabinets.

PVC Laminate Combines Corrosion Resistance with Ease of Fabrication

A new lining material for tanks and equipment is composed of unplasticized polyvinyl chloride on one face and plasticized polyvinyl chloride on the other. The continuous laminate combines the strength and corrosion resistance of the unplasticized material with the flexibility and ability of plasticized polyvinyl chloride to be bonded to steel, concrete or



"Wheels" are not always round: they can be square, geared, trapezoid, large or small—any shape at all. When molded in nylon, they'll be light in weight, long-wearing and strong .They'll withstand abrasion and deterioration. They'll be easy to clean and resistant to acids, alkalies, oils and grease—and, they'll give a distinct competitive advantage to the equipment maker whose products offer these benefits.

If you now use other materials, you'll find you probably can do a faster, better job in plastics by taking advantage of General American's unduplicated production facilities. Ask for further information.

PLASTICS DIVISION
135 South LaSalle Street · Chicago 90, Illinois

Facilities unmatched anywhere: *injection, compression, extruding and vacuum forming, reinforced plastics, painting and assembling.*

For more information, turn to Reader Service Card, Circle No. 382

New Materials, Parts, Finishes

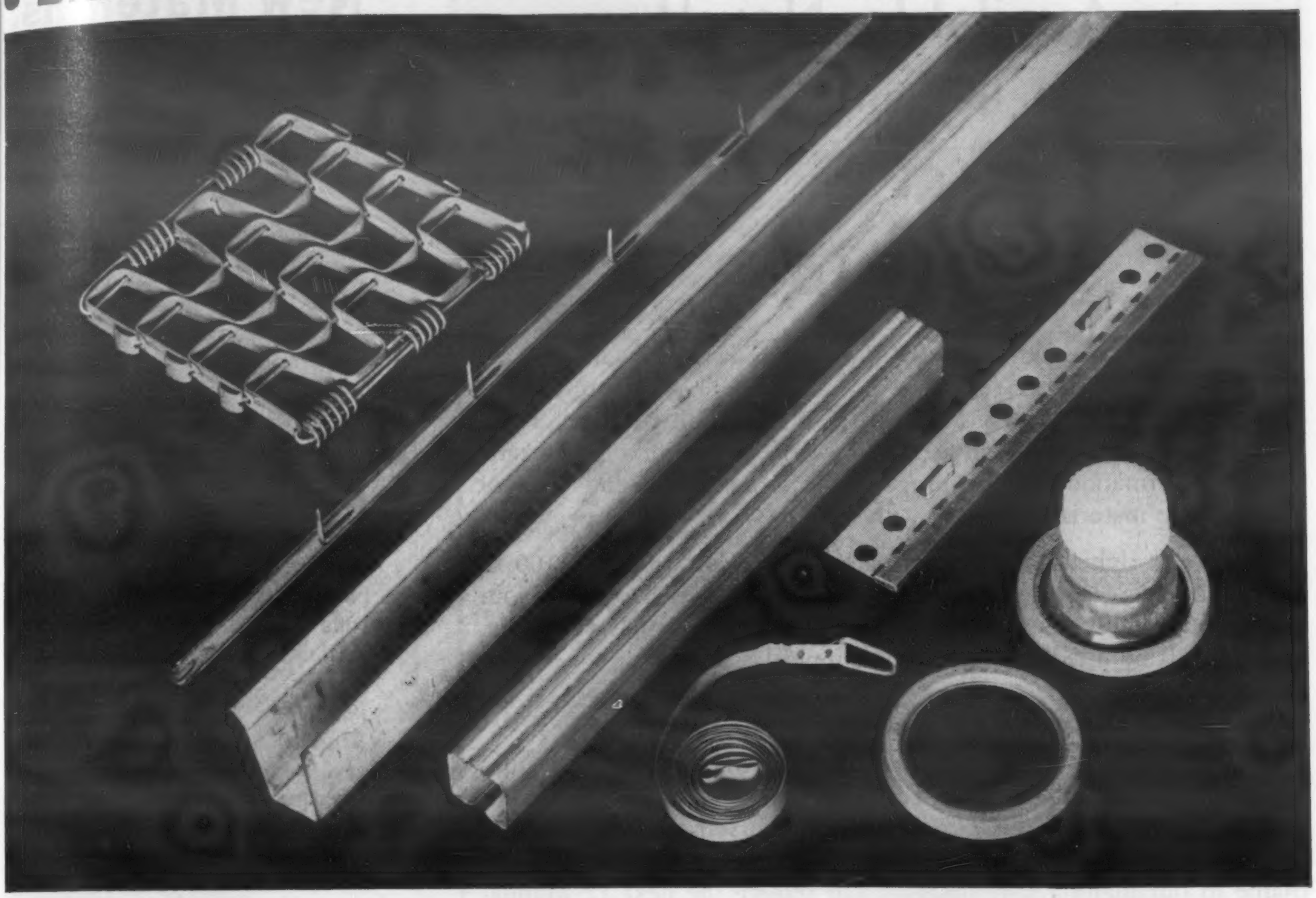
wood. Called Vyflex FL-85, and developed by *Kaykor Industries, Inc.*, Yardville, N.J., the material does not require curing and can be installed rapidly.

Since the exposed face of FL-85 contains no plasticizers or modifiers there is no danger of contamination of process reagents. Unplasticized polyvinyl chloride has good resistance to a broad group of acids, concentrated alkalies, salts and other corrosive organic compounds. Vyflex FL-85 is said to withstand operating temperatures up to 200 F, and to possess high hardness and abrasion resistance.

Fluorocarbon Packing Material

A new Teflon yarn packing designed to function at higher peripheral speeds than ordinary braided tape or molded forms of Teflon has been marketed by *Crane Packing Co.*, Dept. MMN, 1800 Cuyler Ave., Chicago 13. The anti-friction properties of Teflon, Du Pont's fluorocarbon resin, combined with the softness, resilience and fluid retention properties of finer fiber construction enables the packing to run cooler than other types, according to the manufacturers. The packing material possesses all the anti-corrosive, thermal, mechanical and other properties of the fluorocarbon plastics. Where necessary the packing can

• BRAINARD ELECTRO-GALVANIZED STEEL



How to provide parts with a
BUILT-IN PROTECTIVE COATING—at low cost!

Specify Brainard electro-galvanized steel when parts require protection against rust and corrosion . . . you eliminate the coating operation. This pre-coated steel eliminates expensive plating and finishing . . . improves product life and appearance.

The galvanized coating — an integral part of the metal—protects both inside and outside of formed and drawn parts . . . is not affected by forming operations. Coating is hard and uniform, with thickness controlled within .0002.

If your parts require such protection, it will pay you to investigate. Let Brainard quote on your requirements.

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Find out how Brainard's new facilities assure you a dependable source of supply. Send coupon for free booklet.

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COMPLETE STRAPPING SYSTEMS & MATERIALS • WELDED STEEL TUBING • ELECTRO-GALVANIZED STEEL • SCAFFOLDING • PALLET RACKS • BUILDING PRODUCTS

Offices in principal cities throughout the U. S.

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be impregnated with a suitable lubricating material. It is recommended for rugged corrosive service on pump shafts and valve stems, and is available in sizes of 1/8 through 5/8 in., in 1/16-in. graduations.

Alkaline Powder Cleans Metals

Hard water scale, rust, and paint may be removed from ferrous metals by using a water solution of a new alkaline powder manufactured by *Kelite Products, Inc.*, 1250 N. Main St., Los Angeles 12. In a concentration of 3 lb per gal of water at temperatures of 180-212 F, the Kelite Process 235 cleaner is said to remove all such materials in 30-40 min. No electrolytic current is needed. Although the pH factor is exceptonally high, Process 235 is said to be safe on all ferrous metals, but will attack lead, zinc, and aluminum. Its rate of attack on copper is said to be low.

Two New Coating Materials for Metals

Two new coatings, one a phosphatizing material for cleaning and coating ferrous and nonferrous metals, the other a chromate type material which forms a corrosion resistant conversion coating on zinc have been developed by two companies.

Phosphate coating

Klem Kote #1105, a moist white powder produced by *Klem Chemicals, Inc.*, 14401 Lanson Ave., Dearborn, Mich., is said to contain improved accelerators for efficient cleaning of ferrous and nonferrous metals, particularly where carbon smut is a problem. The material is said to produce a tight iron-manganese

These typical properties show why Crucible 430 stainless was a good choice for the Murray worm drive clamp.

Tensile Strength — a. Room Temperature — 75,000 psi. b. At 1700F — 3500 psi
Yield Strength — 40,000 psi
Elongation — 30%
Hardness — 160 BHN
Endurance Limit — 40,000 psi
Creep Strength — Stress for 1% elongation in 10,000 hours at 1300F-1300 psi
Resistance to Scaling — Suitable for continuous service to 1600F.

the finest products wear a STAINLESS *label...*

When you label a product *stainless steel* it means lasting dependability . . . good looks . . . and resistance to wear or corrosion.

That's why the Murray Corporation, Towson, Maryland, chose Crucible stainless for the worm drive hose clamps shown above. These clamps need the high strength, wear and corrosion resistance that only *stainless steel* can provide.

Stainless has other advantages, too. Its high creep and fatigue strength . . . heat resistance . . . and excellent workability may be just what you're looking for.

At Crucible stainless steels are *prescription-made* by steelmen with over a half century of experience in *special purpose* steelmaking. They'll welcome the opportunity to help you make the most profitable use of stainless for your products. *Crucible Steel Company of America, Henry W. Oliver Building, Pittsburgh 22, Pa.*

CRUCIBLE **first name in special purpose steels**

Crucible Steel Company of America

For more information, turn to Reader Service Card, Circle No. 475

New Materials, Parts, Finishes

type coating, and though it can be used in spray or immersion type cleaning equipment, it is recommended for 3-stage spray operations.

Zinc coating

Ker-Chro-Mite GZ, developed by *Kosmos Electro-Finishing Research, Inc.*, 13 Valley St., Belleville, N.J., provides an olive green protective conversion coating on zinc which is said to withstand 100-hr salt spray tests. Designed for use in a zinc bath, the material is supplied in a stable concentrated solution which may be cut to desired strength. The bath does not break down easily and only periodic replenishment with the concentrate is needed. The resultant coating is also recommended as a base for paint.

Two Metallized Pressure-Sensitive Tapes

Two new pressure-sensitive film tapes consisting of aluminum vapor-deposited on polyester film have been marketed by *Minnesota Mining and Manufacturing Co.*, 900 Fauquier St., St. Paul 6, Minn. The Scotch-brand polyester film tapes No. 850 and 852 differ only in that the No. 852 is printable and is supplied with a polyethylene-coated paper liner. The tapes are said to

IF YOU ARE CONSIDERING MOLDING YOUR OWN PLASTIC (thermosetting) PARTS...

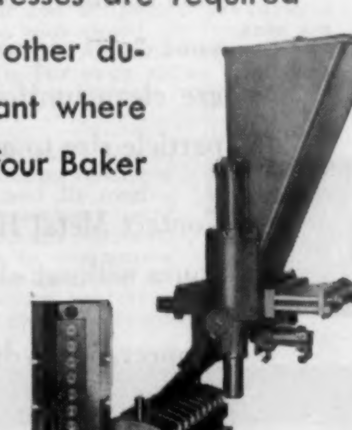
INVESTIGATE...

BAKER *Automatics*

If you use knobs, handles, legs, terminal blocks, switch parts or other plastic parts or metal parts that can be molded of Phenolic, Glaskyd, Urea, Alkyd, Melamine or other thermosetting material and you are considering molding them yourself, investigate BAKER Presses.

One Man Can Operate A Battery

Automatic feeding and the automatic cycle of the Baker Press enable one man to run a battery of ten and even more presses with ample time for spot checks and hopper filling. Where fewer automatic presses are required the operator has time for other duties. For example, in a plant where one man ran a battery of four Baker Automatics, he still had 80% of his time to operate a semi-automatic insert job.



15-25-50-75 & 100 TON MACHINES with MAXIMUM FLEXBIILITY

Real cost savings
Lower rejects
Precision with mass production economy

Versatile presses that can mold many items—all electrical controls included, feeders readily interchangeable. You can switch from one powder to another, from one size feeder to another, and even to the new plastic rope feeder on any BAKER Machine.

DESIGNED AND ENGINEERED BY THE MANUFACTURERS OF MACHINE TOOLS SINCE 1875

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WRITE PLASTIC PRESS DIVISION
BAKER BROTHERS, INC., 1012 POST ST., TOLEDO 10, OHIO

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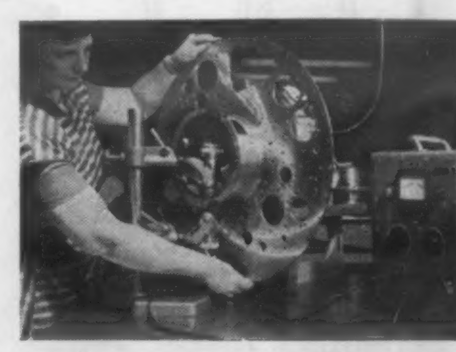
be highly resistant to acids, alkalies, ketones, hydrocarbons, esters, other common solvents and weather conditions. They possess a tensile strength of 25 lb per in. of width, 100% elongation, and an adhesion of 40 oz per in. of width. According to the company the tapes retain their flexibility at low temperatures and have high dimensional stability despite heat and humidity changes. The tapes will not crack, chip or peel. They are available in 1/4 to 23-in. widths on 72-yd rolls. Wider widths and longer roll sizes are available on special order.



Non-Destructive Test Instruments for Metals and Rubber

New instruments recently developed by two companies indicate the increasing interest in ultrasonic methods of non-destructive testing of materials. One, developed by *Sperry Products, Inc.*, Danbury, Conn., has a high degree of flexibility in that it can be used for contact or immersed testing using either signal reflection method or direct transmission. Of the two others developed by *Curtiss-Wright Corp.*, Woodbridge, N.J., one is for direct transmission testing of metals while the other is intended for automatic selective testing of rubber parts.

Reflection or transmission

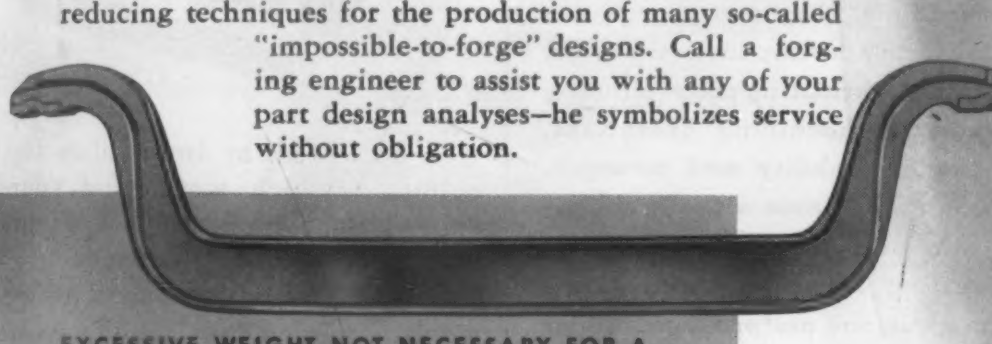
Sperry's Type UW Reflectoscope embodies two search units and can be used for contact testing, where the crystal is placed in direct contact with the metal

Forgings...

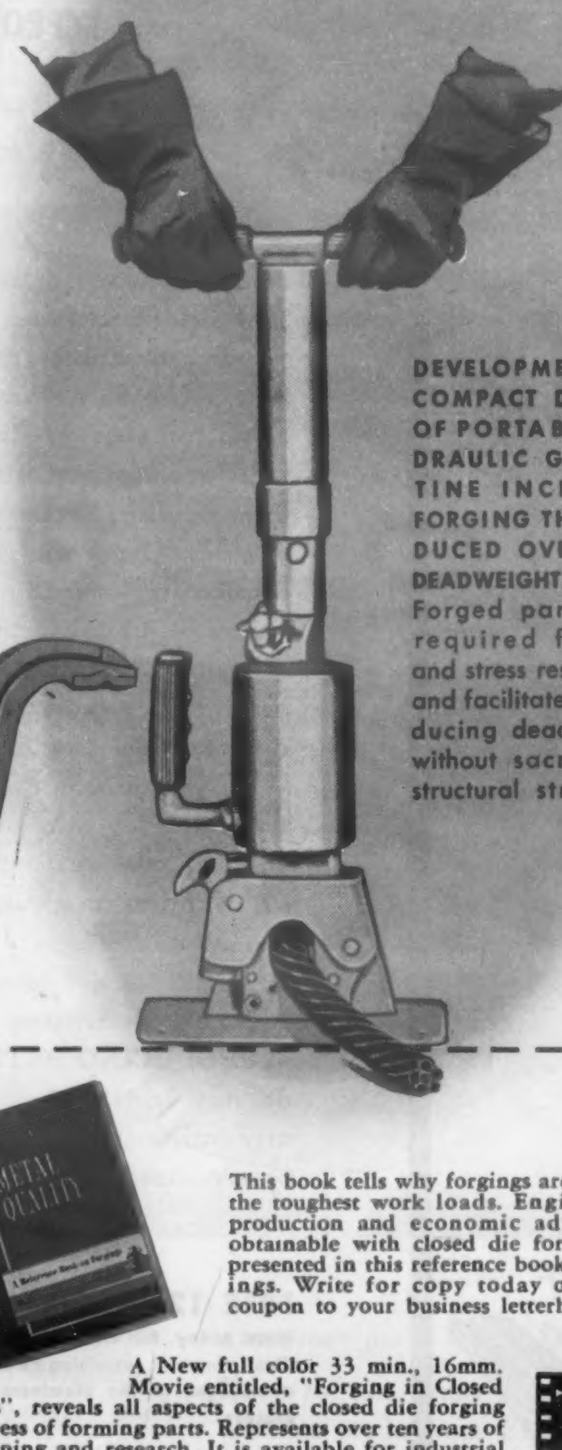
don't need "Deadweight" to make them TOUGH *and* STRONG

Strength is usually determined from the standpoint of just sheer bulk. The elimination of costly, useless deadweight in closed die forging emphasizes the intensified structural strength and added part durability obtainable by this method of production. Forging compacts the grain structure, kneads the steel fibers into a dense mass of flawless part strength. Metal quality can be developed to the exact degree required to meet a specific service condition.

The process of examining the problem of deadweight can be easily checked with the aid of Problem Parts Charts for Design Engineers, Production Executives, Metallurgists and Purchasing Agents. With these aids and consultation with a forging engineer, you can obtain the correct combination of strength and quality without deadweight as well as the many economic advantages of forgings. The forging engineer can also acquaint you with new cost-reducing techniques for the production of many so-called "impossible-to-forge" designs. Call a forging engineer to assist you with any of your part design analyses—he symbolizes service without obligation.



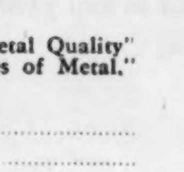
EXCESSIVE WEIGHT NOT NECESSARY FOR A STRONGER PART. This 405 lb. forged I-Beam Equalizer replaced a former 800 lb. unit; saves 395 lbs. of metal, yet is actually a stronger part.



DEVELOPMENT OF COMPACT DESIGN OF PORTABLE HYDRAULIC GUILLOTINE INCLUDED FORGING THAT REDUCED OVER-ALL DEADWEIGHT. Forged parts met required fatigue and stress resistance and facilitated in reducing deadweight without sacrificing structural strength.

CHANGING TO DROP FORGING, PRODUCT NOW WEIGHS 28 LBS. LESS. Manufacturer of this Plate Grip for handling steel plate obtained the extra benefits of safety and strength without increased cost.

This book tells why forgings are used for the toughest work loads. Engineering, production and economic advantages obtainable with closed die forgings are presented in this reference book on forgings. Write for copy today or attach coupon to your business letterhead.



A New full color 33 min., 16mm. Movie entitled, "Forging in Closed Dies", reveals all aspects of the closed die forging process of forming parts. Represents over ten years of planning and research. It is available for industrial training, sales training, instruction in engineering and metallurgy courses at the college level, and for technical, industrial and engineering societies. Write for information about loan of film without cost.

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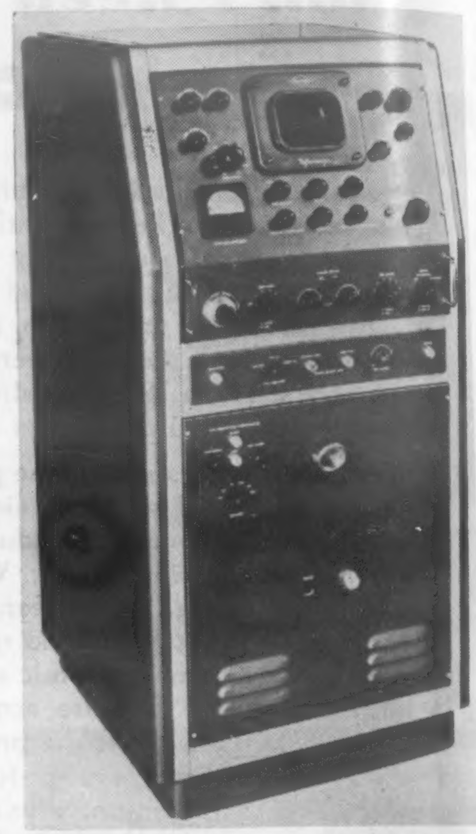
New Materials, Parts, Finishes



to be tested, or immersion testing in which metal and sound heads are immersed in a fluid medium. Under either condition the sound heads can be used for reflection testing, where the pulse is reflected back to the source by both discontinuities and the opposite surface, or for transmission testing in which the signal is picked up on the opposite side of the tested part and any discontinuities in the part alter the pick-up signal. The instrument incorporates both radio frequency (RF) and video presentation. Specifications for either type of presentation can be interpreted with only one instrument.

Pulse rate is variable from 1000 to 60 pulses per sec, which is said to provide better testing at higher scanning rates with higher repetition rates, and testing through material up to 125 ft at lower repetition rates. Pulse frequencies are selectable in 9 frequency ranges from 200 kc to 25 mc. According to the company, immersed testing at 25 mc provides clear, separated signals for closer-to-surface testing and close-to-back reflection. The in-

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New Materials, Parts, Finishes

strument is said to be capable of detecting flaws 0.090 in. below the surface of tested materials.

Direct transmission

The Sonometer, developed by Curtiss-Wright, employs a sonic transmitting head and separate receiving and detecting transducers to view irregularities or discontinuities in the test piece. The sound heads can be changed for angular viewing on odd geometrically shaped or inaccessible objects.

The Sonometer is available with frequencies of 2.85 or 8.5 megacycles per sec. Both units are frequency modulated to insure proper output and avoid standing ultrasonic waves in test material. Two controls simplify use of the instrument. An output control sets the level of ultrasonic output in the incident beam and a sensitivity control sets the level of flaw detectability. A defect is visually indicated by a flashing red light or can be audibly indicated by attaching an alarm to an outlet.

Tests rubber

Designed specifically for testing tires, the Curtiss-Wright tire inspector is an automatic immersion-type direct transmission ultrasonic testing device. The acoustical properties of rubber plus the average size of defects limit the effective frequency range of most ultrasonic tire testers. The Curtiss-Wright tester operates at 100 kc per sec. A transmitting transducer located inside the tire radiates a signal through side walls and treaded areas. A series of pickup transducers searches for tire defects represented by attenuation of the sound signal passing to the outside. The area of tire being tested is immersed in a fluid medium. The tire is automatically rotated through 360 deg at a predetermined speed. It is entirely automatic except for tire insertion and removal.

For more information, Circle No. 508 ➤

Contents Noted

A digest of papers, articles, reports and books of current interest to those in the materials field.

This Month:

- *How titanium applies to chemical industry*
- *Factors in designing plastics for injection molding*
- *Wanted: New outlook on metal creep*

Titanium in the Chemical Industry

Experience with titanium as a construction material in the chemical industry has been limited by short supplies and high prices. For this type of application, however, it would have certain advantages in use which should be investigated, as the titanium supply and price picture is continually changing, and the material may soon become more available for nonmilitary uses.

W.G. Renshaw and P.R. Bish, of Allegheny Ludlum Steel Corp., discuss the advantages which titanium offers the chemical industry in a paper published in the January issue of *Corrosion*. They first point out that no available alloys of titanium have special properties of interest to the chemical industry. Commercially pure titanium, on the other hand, is resistant to a wide range of corrosive substances and is superior to other metals under special operating conditions. It is in these special cases that the authors see the greatest advantage in using the metal.

General corrosion resistance

Titanium has anomolous corrosion characteristics. It is inherently reactive chemically, standing between beryllium and magnesium in the EMF series, yet its corrosion resistance is considerably better than its position would indicate. In neutral or oxidizing environments, titanium exhibits a passive surface condition which places it in the same category as certain other widely used materials of construction. It readily passivates in air and is in its best corrosion resisting condition under these circumstances. Where reducing acids like hydrochloric are involved the potential becomes less noble and attack can occur.

This inherent passive characteristic gives a metal that would otherwise be very reactive, a noble potential and good corrosion resistance under many conditions. In general, it has been established that titanium is most resistant under oxidizing conditions. For example, addition of small percentages of nitric or chromic acid to sulfuric will inhibit attack completely. Similarly, oxidizing agents are also effective in hydrochloric acid, and copper in phosphoric acid prevents attack.

Specific resistance

One of the most promising uses for titanium is in handling of chloride salts. It has exceptional resistance to corrosion in sea water and other brines. It is practically unaffected by other corroding agents like ferric, stannic or mercuric chloride and the hypochlorites. Use of inhibitors in hydrochloric acid will extend titanium's range of usefulness when the metal is exposed to high concentrations of the acid.

Titanium shows extremely good resistance to pitting or localized surface attack under all conditions. In chlorides it offers its most promising possibilities. It shows exceptional resistance to pitting even in severe pitting reagents such as ferric chloride and cupric chloride or hypochlorites. It is also resistant to attack by stagnant conditions, surface deposits, fouling marine organisms and moist salt crystals.

Titanium has excellent resistance to all concentrations of nitric acid. Its corrosion rate in red and white fuming nitric acid is practically negligible and it is unaffected in highly concentrated solutions of chromic acid. Corrosion rate of cast titanium in nitric acid at elevated temperatures and pressures has been reported as less than 0.005 in. per year.

Resistance of titanium to molten sulfur and sulfur compounds points to successful applications in equipment for handling these materials. Moist gases containing sulfur dioxide or hydrogen sulfide often cause localized attack in the usual materials of construction. The authors point out that solutions of sulfuric acid, unless inhibited by an oxidizing agent should not be included.

There are some conditions which titanium may not satisfy and some applications in which it will never supplant existing materials in use. At present, titanium shows no promise in phosphoric acid applications or where highly concentrated hydrochloric or sulfuric acid is involved. Development of alloys or modifications to overcome these deficiencies should eventually receive attention.

(More Contents Noted on page 172)

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Designing for Injection Molding

In the injection molding of thermoplastic resins there are many design principles which must be understood and reckoned with to produce an economical product. The approach to designing an injection molded plastics product which can be economically processed may be broken down into four areas of planning, each of which has a specific effect on low-cost processing. The areas are: detail design features, material selection, tolerance specifications and finishing requirements. In the January-February issue of General Motors' *Engineering Journal,* R.W. Forward of the Inland Mfg. Div. discusses these various aspects of design and how they affect the over-all manufacturing costs of plastics moldings.

Detail design

Various detail design features such as mold tolerances, fillets and radii, draft allowance, taper, undercuts, inserts and color requirements must be properly considered, since improper design features result in high mold costs, poor quality moldings, or both. Finished tolerances are controlled by the accuracy possible in building the mold cavity and on shrinkage rate of the molded material. A ± 0.005-in. working tolerance on critical dimensions is recommended. Where greater accuracy is required ± 0.002 in. can be held. However, closer tolerances will result in a 15 or 20% increase in mold cost.

Generally, the use of fillets and radii results in lower mold cost. More important, however, is the improved quality of molding resulting from their use. They permit easy flow of plastics into the cavity, reduce the chance of air entrapment, lessen stress concentrations in sharp corners, add strength to cavity and molded piece, and will not

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reflect blemishes as much as sharp angles will.

Draft is recommended wherever possible, 2 deg being usual for all sections perpendicular to parting line. Undercuts increase the cost of the molding and should be avoided wherever possible. In some cases it may be more economical to machine undercuts rather than mold them. Cross-sectional design should be uniform and as thin as strength requirements will allow. Disadvantages of irregular cross-sections may be summarized: 1) uneven shrinkage rates make tolerances harder to hold; 2) presence of internal stress concentrations result in over-all weakening effect; 3) undesirable material flow characteristics are produced in the cavity; and 4) closed mold time is increased due to longer normalization period required to prevent severe distortion.

Inserts molded in a product should be surrounded with enough plastics to absorb shock and to prevent fracture. Inserts should be designed with chamfered edges and radii at all corners. In regard to color, the author points out that possibilities of plastics molding resins is practically unlimited. Where different colors are desirable in different areas of a molding, they must be molded in separate operations, unless a marble effect is desired.

Materials selection

Selection of a material to meet the requirements of the finished part depends on strength required, color effect, and surroundings to which the product will be exposed. Selection of material which will be economical to process depends on the material's flow characteristics, thermal conductivity, uniformity of granular structure, plasticizing rate, purity, machining qualities, effect of metal inserts and shrinkage rate. Five thermoplastic compounds widely used at Inland Manufacturing are


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polyvinyl chloride, cellulose acetate butyrate, polystyrene, polyethylene and methyl methacrylate.

Tolerances

Tolerances possible with each material are determined by shrinkage rates and location of cavity gates. In injection molding, high internal stress concentrations are built up within the mold cavity after the ram has reached its full forward position. This stress condition tends to distort the piece following its removal from the mold and also results in contraction of material about the gate. Contraction and high stress concentrations must be kept in mind by the designer in order to plan allowances for gate positioning. Where possible, gating should be in non-central locations so that finishing operations involved in removing gates will be kept to a minimum.

Finishing

Both decorative and nondecorative designs usually require common finishing operations such as removing gates, sanding flash lines, buffing and final cleaning. Decorative designs often require additional painting and metal-vapor coating. Processing operations required in finishing plastics products that should be considered in design work are gate positioning, painting and metal-vapor coating, and final buffing and cleaning.

Location of the cavity gate is an important factor in the appearance of decorative designs as well as in the cost. For instance, the flow characteristics of acrylic resins are such that weld lines and flow lines are unavoidable. Degree of noticeability of these lines can be reduced if the designer is familiar with their causes, i.e., design features which restrict or divide the flow of plastics as it fills the cavity. Large gates permit rapid injection of plastics material

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and lessen the noticeability of flow and weld lines.

Cost of painting or metal-vapor coating a product may make up a substantial part of the total cost of a product. Design features should be planned so that painting and vaporizing masks may be positioned effectively during these operations. Metal vaporizing is used when the design calls for a genuine metallic appearance. In some cases, lower cost metal-base paints can be substituted when the finishing requirements do not dictate a brilliant metallic appearance.

Plea for a New Outlook on Creep

A plea has been made for a new outlook on the problems of creep in metals. It is based on the fact that new and important questions concerning creep behavior of alloys are arising at a rate that far exceeds our physical or financial capacity to solve them by the currently popular procedures of empiricism. In a paper delivered before the 57th Annual Meeting of the American Society for Testing Materials in June last year, J.E. Dorn and L.A. Shepard of the University of California outlined what we need to know about creep, and suggested a method of approach to the study of high-temperature and lower-temperature creep of pure metals and complex alloys.

The authors explain that by means of new types of experiments we must seek a more intimate fundamental knowledge of the basic laws of creep. They attribute failures of earlier theories of creep to the facts that: 1) they were based on limited knowledge gained from a few simple steady load, constant temperature creep data on simple materials; 2) in general, the effect of structural changes that attend creep on subsequent creep properties were neglected; 3) no attempt was made to isolate for separate experimental study each

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individual assumption made in the composite theory. The authors are agreed that any new theory of creep based on current knowledge will probably be as unrealistic as former creep theories. Rather than new theories, fuller understanding of basic creep laws is required. A thorough grasp of basic creep laws will permit creep predictions for desired conditions of stressing and temperature from a minimum of short-time experimental data.

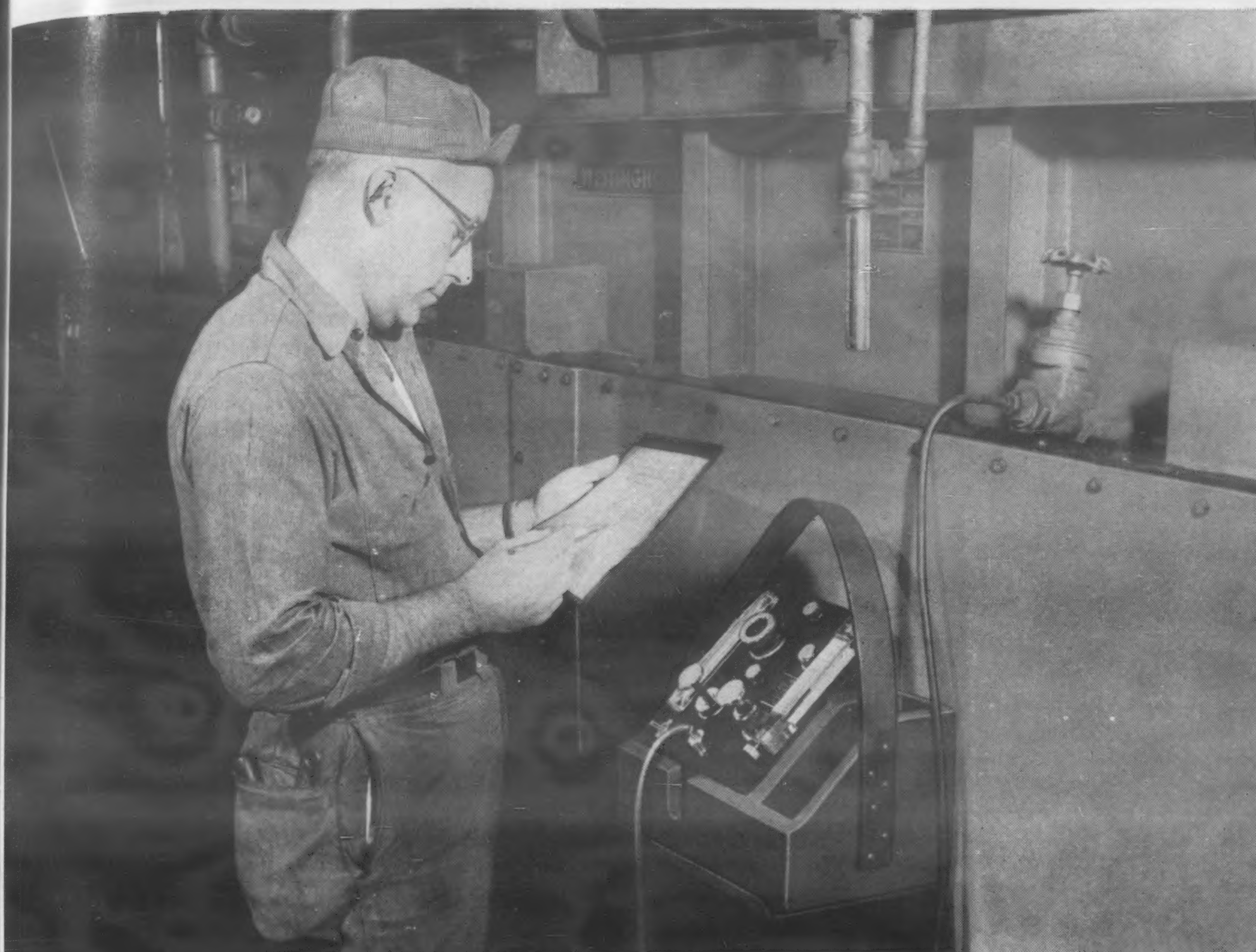
The authors discuss creep laws for high temperatures and point out important areas where additional research is necessary. They also emphasize the need for uncovering basic laws for low-temperature creep in light of its engineering importance. Empirical procedures for creep testing should be supported only for design problems of immediate and future interest in cases where the exact condition of alloys and histories of stress and expected service temperatures can be specified. Otherwise costly useless data that cannot be correlated will remain buried in unknown and uninteresting reports. Finally, Messrs. Dorn and Shepard emphasize the temporal and financial advantages that will be gained when sound laws for creep can be formulated with assurance.

Books . . .

Titanium in Iron and Steel. *George F. Comstock. John Wiley & Sons, Inc., New York 16, N.Y. 1955. Cloth, 6 by 9 in. 294 pp. Price $6.00.*

This book, the third in the new series of Alloys of Iron Monographs, is a critical review of the important data published on the use of titanium in iron and steel.

The book opens with a discussion of titanium minerals, metallic titanium and phase diagrams. Chapters deal with titanium as a deoxidizer in rimmed and killed



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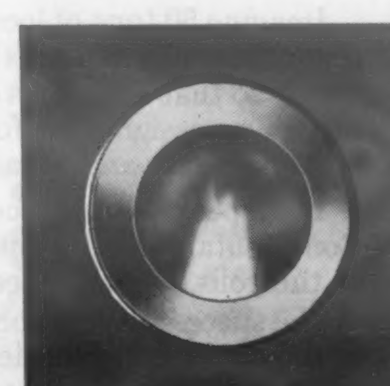

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Books . . .

wrought steels, cast steels and cast irons, and the effect of titanium on nitrogen and sulfur. The role of titanium as an alloying element in low alloy and stainless steels is discussed, and a final chapter covers the titanium-bearing precipitation hardening steels and heat resisting alloys. A bibliography of about 300 references to world literature sources is included.

This book, like the earlier ones in the series, offers the metallurgist and engineer a reliable source of information on the effects of titanium in ferrous metals and a foundation for further research in the field.

Electroplating Engineering Handbook. *Edited by A. Kenneth Graham. Reinhold Publishing Corp., New York 22, N.Y. 1955. Cloth, 7 by 10 in. 650 pp. Price $10.00.*

This book deals with the engineering aspects of electroplating. With this objective, various types of equipment are evaluated and compared and processes are discussed without specific limitation as to proprietary interest or individual designs.

The book is divided into two parts. Part 1 covers general processing data and contains chapters dealing with cleaning, electropolishing, metal surface treatments, typical bath compositions, tables of data and information on the design of parts.

Part 2 covers the engineering of plating installations including current sources, plating machines, heating and cooling systems, filtration, exhaust systems, auxiliary equipment and general maintenance.

The treatment of the subject matter has been designed to make the book particularly valuable to the electroplater and the electroplating engineer. It will be a useful tool also for the designer and manufacturer of electroplating equipment.

(More Books on page 184)


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Books . . .

Titanium in Industry. *Stanley Abkowitz, John J. Burke and Ralph H. Hiltz, Jr. D. Van Nostrand Co., Inc., New York 3, N.Y. 1955. Cloth, 6 by 9 in. 224 pp. Price $5.00.*

This book is a survey of the status of titanium today. Its coverage is limited to titanium as a primary metal; uses as the oxide or as an alloying element are touched on only briefly. The book is dedicated to Colonel Benjamin S. Mesick who states in a foreword, "I feel that this primer on titanium will stimulate and accelerate this new industry as similar publications did when steel was in its infancy".

The book is divided into ten chapters dealing with production techniques, properties of the metal and its alloys, heat treatment, forming, joining, machining and grinding, surface properties, analytical and metallographic techniques, selection of materials and applications. Each chapter contains a bibliography. Many illustrations are included to supplement the text. Metallurgists and engineers will find much useful information included.

Surface Coatings and Finishes. *Philip L. Gordon and George J. Dolgin. Chemical Publishing Co., Inc., New York, N.Y. 1954. Cloth, 5½ by 8½ in. 299 pp. Price $9.00.*

This book is designed to review briefly the standard methods of preparing and using the orthodox varnish vehicles and to describe in detail the structure, use and practical value of the plastics materials now available for surface coatings.

Its ten chapters deal with oleoresinous-varnish technology, surface coatings from synthetic resins and polymers, alkyd resins, phenol-aldehyde resins, urea-formaldehyde resins, cellulose derivatives, synthetic high polymers, rubber derivatives, miscellaneous plastics and testing methods. Each chapter contains a bibliography.

The numerous tables, graphs

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and other illustrations and the apparatus and techniques described will aid manufacturers, research scientists and users to determine the most effective application of these synthetic materials.

Dictionary of Metallography. *R. T. Rolfe. Published by Chemical Publishing Co., Inc., New York, N.Y., 1955. 6 by 9 in. 287 pp. Price $5.75.*

Definitions, reference listings, and pertinent terms from collateral sciences are given encyclopedic treatment in this volume. Discussions of theory and practice and cross references make this a convenient reference book for the metallurgist and for the engineer.

Metal-to-Metal Adhesives for the Assembly of Aircraft. *Edited by R. G. Newhall. Published by Western Business Publications. San Francisco, Calif., 1955. Paper bound, $8\frac{1}{2}$ by 11 in. 64 pp. Price $4.00.*

Fabrication, design, testing, flight experience and theoretical aspects of adhesive-bonded metal structures are covered in this collection of twelve papers presented at the Conference on Metal-to-Metal Adhesives, sponsored jointly by the University of California and the Aircraft Industries Assoc. of America in Sept., 1954.

The New Practical Formulary. *Mitchell Freeman. Published by Chemical Publishing Co., Inc., New York, N.Y., 1955. $8\frac{1}{2}$ by $5\frac{1}{2}$ in. 376 pp. Price $7.95.*

Formulas are listed and explained with accompanying descriptions and instructions in this reference book for the chemist or investor in chemical industries. The first part of the book gives an outline of the chemical manufacturing plant and contains instructions for carrying out basic operations such as heat-

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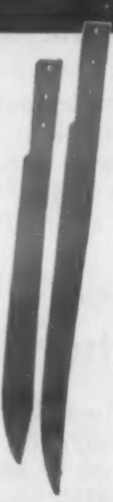

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Books . . .

ing, filtering and evaporating. Separate sections cover individual branches of the chemical industries, including alloys, pharmaceuticals and waterproofing. An appendix and bibliography contain tables on weight conversion, Baume degrees, temperatures, etc., including a selected list of sources of supplies and machinery.

Reports . . .

Notched Aluminum Experimental Investigation of Notch-Size Effects on Rotating-Beam Fatigue Behavior of 75S-T6 Aluminum Alloy. *W. S. Hyler, R. A. Lewis, and H. J. Grover, Battelle Memorial Institute, Nov. 1954. NACA TN 3291, 47 pp, diagrams, photographs, 12 tables. Available from the National Advisory Committee for Aeronautics, 1512 "H" St., N.W., Wash. 25, D.C.* Investigation was initiated to study the influence of size, particularly the notch size, on extruded 75S-T6 aluminum-alloy test specimens. Unnotched and notched specimens with five different minimum-section diameters were tested. For each size a semicircular groove was tested and for the largest diameter specimen a V-notch was also tested. A method of surface preparation was selected that would produce comparable surface finishes in different-sized notched and unnotched specimens.

High Temperature Materials Tensile and Compressive Stress-Strain Properties of Some High-Strength Sheet Alloys at Elevated Temperatures. *Philip J. Hughes, John E. Inge, and Stanley B. Prosser, Nov. 1954. NACA TN 3315, 32 pp, diagrams, photographs, 6 tables. Available from the National Advisory Committee for Aeronautics, 1512 "H" St., N.W., Wash. 25, D.C.* Results of tensile and compressive stress-strain tests at temperatures up to 1200 F are presented for SAE 4340, Hy-Tuf, Stainless W, and

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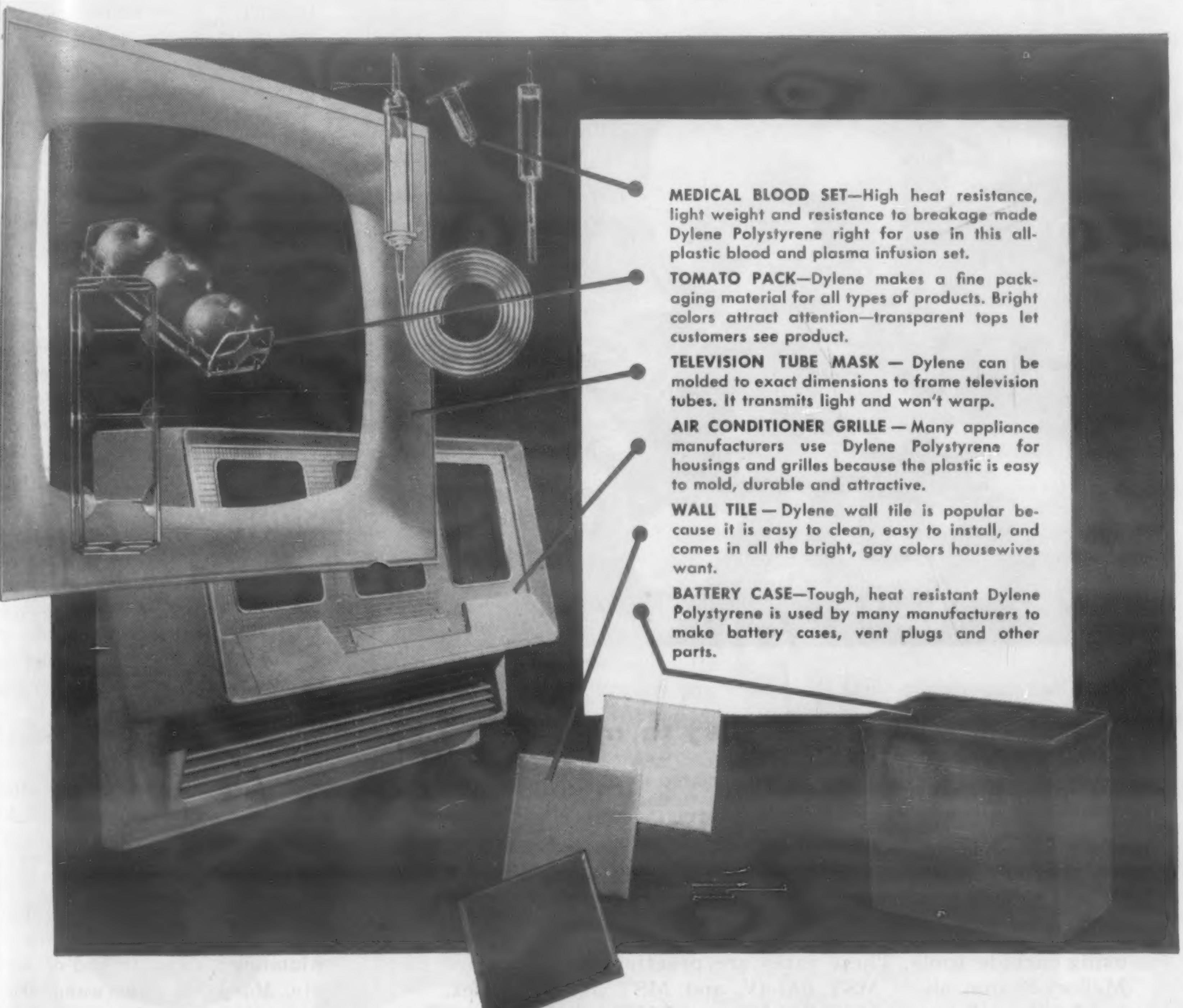

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Reports . . .

Inconel X sheet materials which had ultimate tensile strengths at room temperature in the 170 to 220 ksi range. Representative tensile and compressive stress-strain curves are given for each material at the test temperatures. Secant and tangent moduli, obtained from the compressive data, are included.

Adhesive Bonding Investigation of Adhesives: Metal-to-metal bonding. *Jack F. Furrer and William A. Merlack, U. S. Chemical Corp, Chemical and Radiological Laboratories, Army Chemical Center, Md., Apr. 1954. PB 111445, 15 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Wash. 25, D.C. $.50.* The object of the work described in this report was to investigate the use of resinous-type adhesives as a replacement or alternate for soft solder in bonding galvanized steel screens to cold-rolled steel shrouds in the tail fin assembly. Tensile tests of the adhesives investigated were compared with soft solder after storage in three climatic conditions—desert, tropical, and arctic.

Bonding Cermets Exploratory Study of the Metal Bonding of Aluminum Titanate and of Mullite. *Margaret Pausewang, Ohio State University Research Foundation, Columbus, Ohio, Mar. 1953. PB 111436, 10 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Wash. 25, D.C. $1.00.* The good high-temperature properties of mullite are well known, and recent investigations have indicated that stabilized aluminum titanate might make a good ceramic component for a cermet body. This report covers an exploratory study of the metal bonding of these two materials, one of which is an aluminum silicate and the other an aluminum titanate.

Welding Molybdenum Production of Sound Ductile Joints in

Heavy-duty crane parts show how shock-resistant

G-E RUBBER-PHENOLICS

can take
* rugged service
* moisture
* freezing weather

Three mighty important reasons dictate the choice by Electric Service Manufacturing Company, Philadelphia, of General Electric rubber-phenolic molding compound. This shock-resistant plastic helps ESM make eye bolts and strain insulators for heavy-duty cranes with—

1. **Ruggedness**—resists abuse yet is easy to mold
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3. **No tendency to crack**—even under freezing conditions.

Where can YOU use G-E rubber-phenolics? Shock-resistant G-E rubber-phenolics offer you an ideal plastic for applications where high impact strength and resiliency are "musts." They produce parts which resist breakage in assembly and service, accommodate large metal inserts without cracking, and permit lightweight designs without heavy reinforcement.

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Sect. 520-3, Chemical Materials Dept.
Pittsfield, Massachusetts

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For more information, turn to Readers Service Card, Circle No. 491

Contents Noted

Reports . . .

Molybdenum. *Fifth progress report for period Jan. 30 to July 17, 1953 under Contract No. AF 33 (616)-10. M. I. Jacobson, D. C. Martin, and C. B. Voldrich, Battelle Memorial Institute, Columbus, Ohio, July 1953. PB 115184, 21 pp, photographs, drawings, diagrams, graph, tables. Available from Library of Congress, Publication Board Project, Wash. 25, D.C. Microfilm $2.25, Photocopy $4.00.* An investigation of the production of sound and ductile welded joints and brazed joints in Mo is presented. A slotted-type tension specimen was developed for determining the shear strength of brazed joints. The results showed that the best non-cobalt-base alloy was inconel. The best Co-base alloy was Haynes Alloy 25.

Low Temperature Metals Research and Development of Metals and Alloys for Low Temperature Applications. *Panel on Metals for Use at Low Temperatures, National Research Council, Div. of Engineering and Industrial Research, Minerals and Metals Advisory Board, Apr. 1954. PB 111453, 77 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Wash. 25, D.C. $2.00.*

High Temperature Alloy System Survey of Portions of the Chromium-Cobalt Nickel-Molybdenum Quaternary System at 1200 C. *Sheldon Paul Rideout and Paul A. Beck, U. S. National Advisory Committee for Aeronautics, 1953. PB 115081, 40 pp, photographs, diagrams, graphs, tables. Available from Superintendent of Documents, Government Printing Office, Wash. 25, D.C. $.35.*

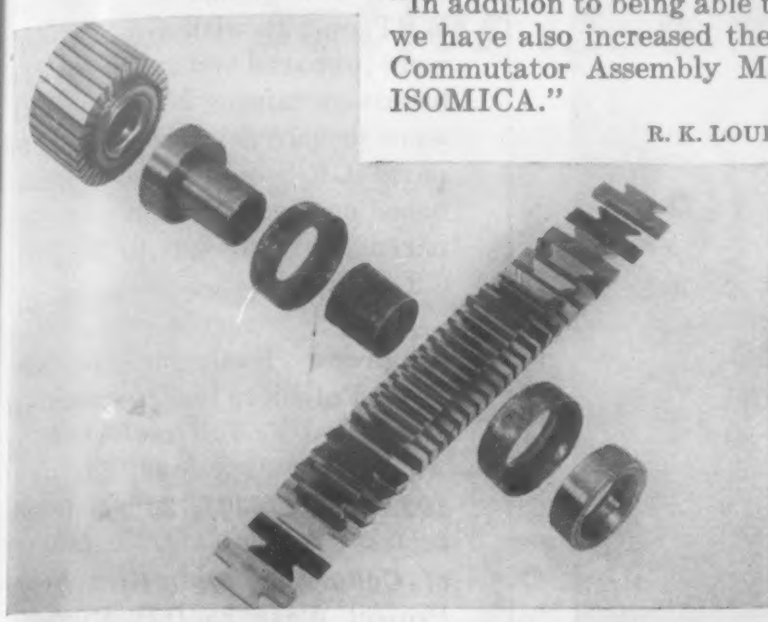
Rubber Blends Evaluation of Neoprene-GR-S Rubber Blends. *Paul M. Rogers, U. S. Arsenal, Rock Island, Ill., July 1953. PB 115302, 15 pp, tables. Available from Library of Congress, Publication Board Project, Wash. 25, D.C. Microfilm $2.00., Photocopy*

ISOMICA® Segments Improve Commutator Production

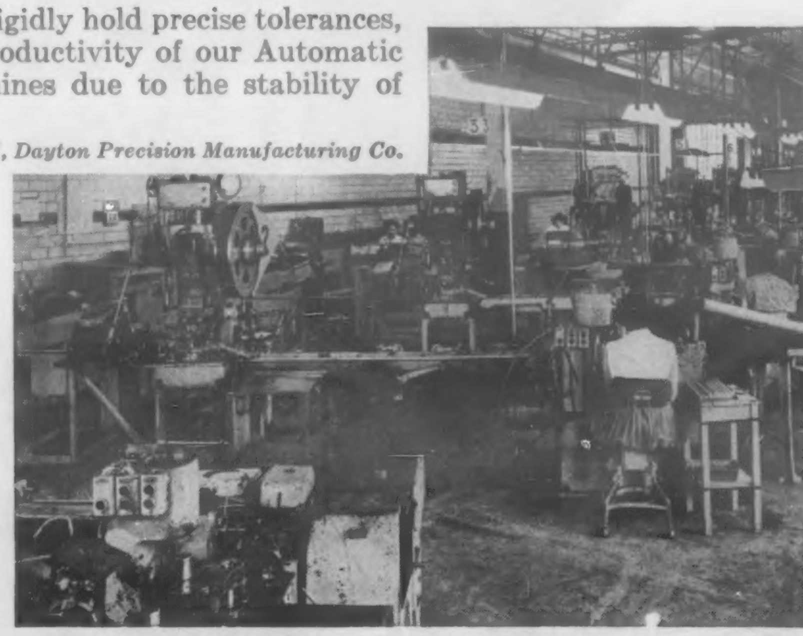
—*reports Dayton Precision Manufacturing Co.*

"In addition to being able to rigidly hold precise tolerances, we have also increased the productivity of our Automatic Commutator Assembly Machines due to the stability of ISOMICA."

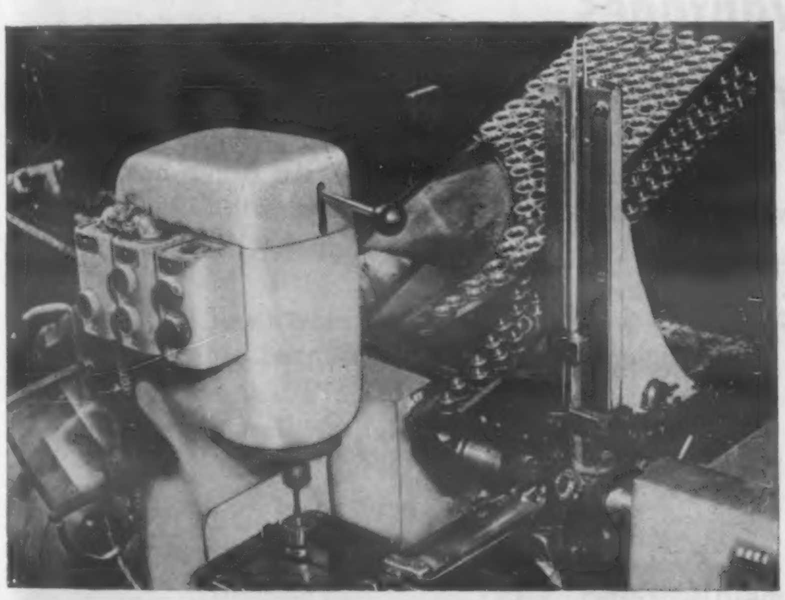
R. K. LOUDEN, *Dayton Precision Manufacturing Co.*



1. Completed assembly and components for Dayton aircraft dynamotor commutators. Uniformity and good physical stability of ISOMICA enabled Dayton to bring tolerances well within limits set by strict military specifications, and to improve the efficiency of machine assembly.



2. Automatic assembly of commutators is done on special patented machines. Copper stock from reels feeds through blanking press. Blanked segments are combined with precut, matching ISOMICA insulating segments in assembly unit. ISOMICA does not tend to de-laminate or split—an important advantage in automatic handling.



3. Close-up of assembly operations shows ISOMICA and copper segments ready to be staked to mica and steel core parts. As one assembly is staked on hydraulic press to left, another collection of segments is completed in rubber collets which index proper number of bars.

4. After baking, machining and coining, commutators get careful tests and final precision inspection to determine any deflection within 0.0001". ISOMICA gives uniform insulation thickness and continuity throughout commutator's service life.

Whatever electrical insulation material you need—Class A to Class H—standard or special—MICO makes it best. We manufacture it, cut it to size, or fabricate it to your specifications. We'll be glad to work with you on your electrical insulation problems. Write, or send us your blueprints or specifications today.

MICO

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For more information, turn to Reader Service Card, Circle No. 446

Contents Noted

Reports . . .

$2.75. Ten blends of Neoprenes WRT or FR with GR-S (x600) were prepared and evaluated. The blends containing Neoprene WRT were prepared in ratios up to 50 parts GR-S while those blends based on Neoprene FR were prepared in ratios up to 30 parts GR-S (x600).

Neoprene Evaluation of Neoprene Polymers for Ordnance Applications. *Z. T. Ossefort, U. S. Arsenal, Rock Island, Ill., June 1953. PB 115303, 20 pp, graph, tables. Available from Library of Congress, Publication Board Project, Wash. 25, D.C. Microfilm $2.00, Photocopy $2.75.* Evaluation data is noted on neoprene types GN, RT, W, and WRT from the general purpose category and on Types Q, S, and FR from the special purpose group. A short description of the polymers and reasons for evaluation is presented. Results of evaluation of a series of blends of neoprene Type S with other neoprene polymers using high plasticizer concentration (with object of improving the low temperature characteristics of the neoprenes) are presented.

British Nylon Specs Aircraft Material Specification: Nylon Fabric. *Gt. Brit. Ministry of Supply, May 1954. PB 115119, 3 pp. Available from British Information Services, 30 Rockefeller Plaza, New York 20, N.Y. $.30.*

Nylon Friction Friction and Lubrication of Nylon. *R. C. Bowers, W. C. Clinton, and W. A. Zisman, U. S. Naval Research Laboratory, July 1954. PB 111510, 13 pp, tables. Available from Office of Technical Services, U.S. Dept. of Commerce, Wash. 25, D.C. $.50.* The static and kinetic friction for steel against nylon and for nylon against nylon both dry and lubricated have been studied. Lubricants studied included water, ethylene glycol, glycerine, fatty acids, paraffins, silicones, an alcohol, an amine and a fluorinated acid, amine and hydrocarbon.

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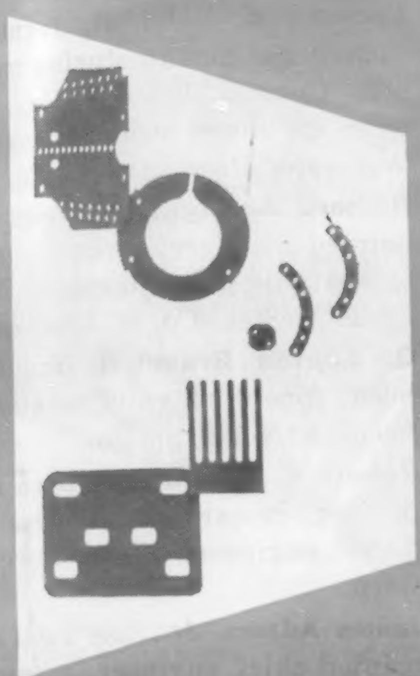
might be your answer to better insulation at lower cost



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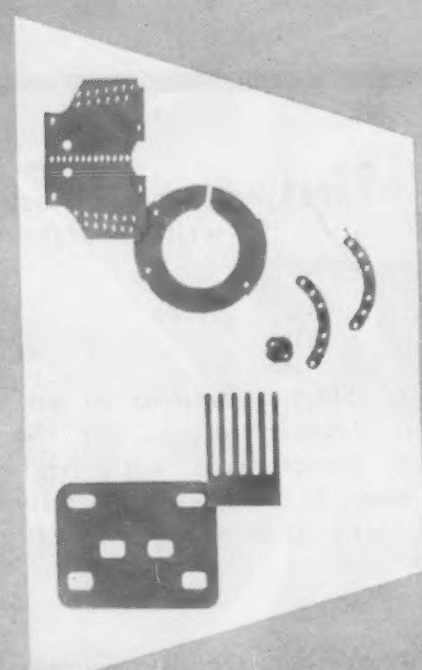
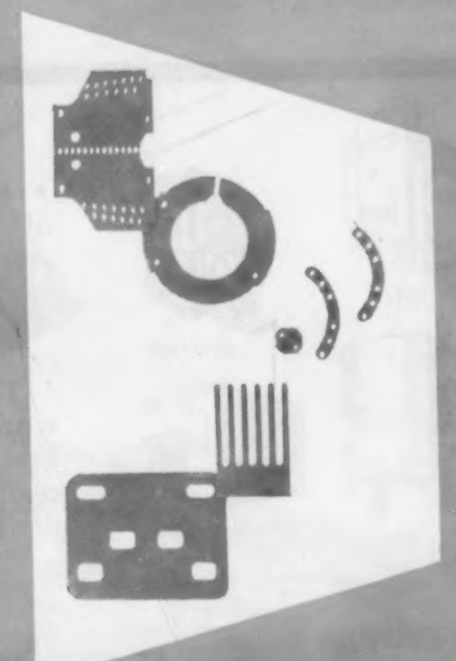
PLAIN

Fibrous sheet material for use as replacement for paper-base laminates where moisture absorption is not a critical factor. Arc resistance, tensile and impact strengths of DUROID 800 are greater than XP paper-base laminates. Listed by Underwriters' Laboratories.



DUROID 800
COATED

Moisture pick-up almost as low as paper-base laminates; flexural strength much higher. Specific coatings — such as alkyds, epoxies and vinyls — can be applied to obtain characteristics available only in much more expensive materials.



DUROID 800
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Retains more physical strength after exposure to flame. Self-extinguishing, with no afterglow. Easy to fabricate. Your tests may prove it satisfactory for applications now using much more expensive materials.

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news of ENGINEERS COMPANIES SOCIETIES

NEWS OF ENGINEERS

Leonard C. Schmidt, formerly manager of manufacturing methods, General Electric Co., has been appointed works manager, Worcester Pressed Steel Co.

Richard A. Biggs has been appointed manager, product development, of the Stainless Div., Crucible Steel Co. of America.

G. Lupton Broomell, Jr., has been appointed chief engineer, Leeds & Northrup Co.

Robert F. Renkin has been appointed research and development engineer, Sharon Steel Corp.

James Adams, Jr., has been appointed chief engineer, research and product design, Manhattan Rubber Div., Raybestos-Manhattan, Inc.

B. J. Milleville has been appointed chief engineer at Edward Valves, Inc., subsidiary of Rockwell Manufacturing Co.

Frederic L. Moffet has been made chief metallurgist, Park Works, Crucible Steel Co. of America.

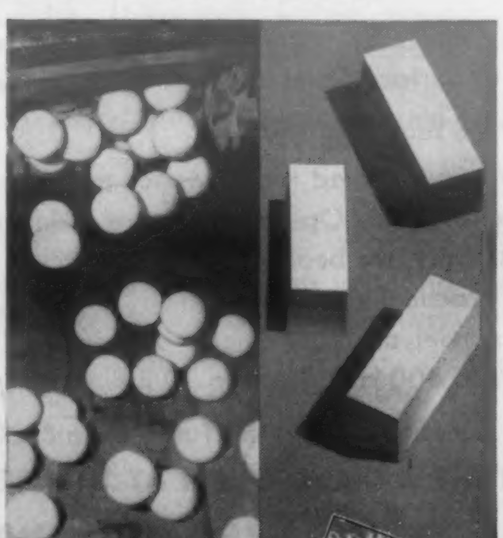
Frank R. Benedict has been appointed to the newly created position of manufacturing engineering manager, Sturtevant Div., Westinghouse Electric Corp.

Paul A. Pitt has been named chief engineer and **Philip M. Klauber,** chief administrative engineer, Solar Aircraft Co. Solar's Engineering Div. was recently formed by combination of the Design Engineering and Development Engineering Div.

John D. Gordon has been appointed director of manufacturing engineering, Studebaker-Packard Corp.

Dr. Alex Sacher has been named technical director, Standard Insulation Co.

Melvin P. Espy has been appointed to the newly created position of assistant director of



engineering, Anaheim Div., Northrop Aircraft, Inc.

Russell T. Lowe has been made assistant chief engineer and **Richard D. Cavanaugh,** technical assistant to the chief engineer, the Barry Corp.

Joseph P. Green has been appointed director of engineering, the Swartwout Co.

Charles H. Frantz has been appointed executive director of new product development, Chicago Molded Products Corp.

R. B. Osbourne has been elected to the newly created post of vice president engineering, Phillips Corp.

Charles B. Johnson, consulting engineer at Rockwell Manufacturing Co. and former chief engineer of several Rockwell divisions, has retired after nearly 44 years in the engineering field.

Warren H. Brand has been elected vice president in charge of engineering and research, Conoflow Corp.

Dr. Walter A. Dean, chief metallurgist of Aluminum Co. of America's Cleveland works, has been named to coordinate technological developments in titanium with Alcoa's titanium activities.

William C. Seitz has been appointed manager, research and development, Firth-Loach Metals, Inc.

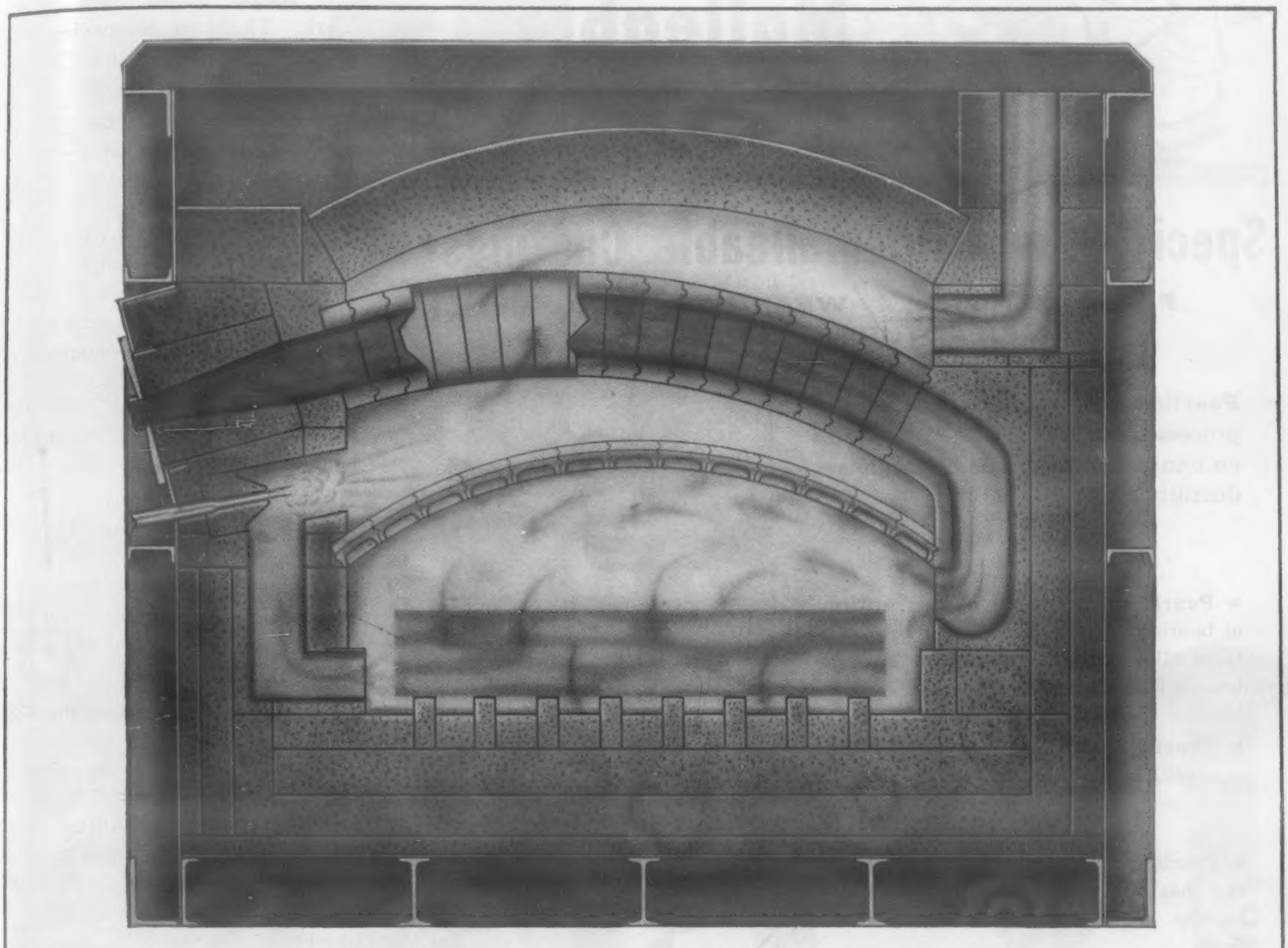
Albert De Chiara, Jr., has been elected vice president and general manager and **Albert J. Carter,** vice president in charge of engineering, Drico Industrial Corp.

Howard C. Parkman has been named assistant vice president-operations, Vanadium Corp. of America. Other new appointments in the company include **R. T. Bailey** as assistant to the vice president-production manager, and **C. A. J. Schulte** as plant manager at Niagara Falls.

Allan Nichamin has been named to manage the new national Aluminum Dept., Federated Metals Div., American Smelting and Refining Co.

(News of Companies on page 200)

Another Norton ℞ on the job!



Cross-section of a Lithium Company two-stage hot atmosphere recuperative furnace for scale-free heating of ferrous and non-ferrous metals for precision forging and rolling. The segmented conduit, a Lithium Company design, is made of Norton CRYSTOLON tongue and groove tiles. Fired shapes of this same material form the side walls. Burner block is of ALUNDUM refractory material.

Lithium Company specifies long-life ALUNDUM and CRYSTOLON* refractory shapes for its atmosphere furnaces*

The Lithium Company of Newark, N. J., well-known builder of atmosphere furnaces, reports excellent results from Norton refractories.

The Lithium designed refractory shapes are Norton CRYSTOLON Silicon Carbide. They were selected for their hot strength, high refractoriness, thermal conductivity, and low thermal expansion. They give long, trouble-free service life at temperatures up to 2900°F. ALUNDUM refractory material was the choice for the burner block because of its high refractoriness and resistance to chemical influences at temperatures up to 3450°F.

For your own furnace operations

It will pay you to investigate how Norton ℞'s — *engineered and prescribed* refractories — can help you save time, work and money. See your Norton Representative or write to NORTON COMPANY, Refractories Division, 343 New Bond Street, Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto 5, Ont.

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Making better products... to make your products better

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

For more information, turn to Reader Service Card, Circle No. 358

news of | COMPANIES

Mack Trucks, Inc., as the first major step in a long range product diversification program, has acquired **White Industries, Inc.,** and **Radio Sonic Corp.,** New York. The two companies will become the Electronics Div. of Mack Trucks.

The **American Brass Co.** has announced plans for construction of a new brass mill in the Paramount district of Los Angeles. The new mill will be built for the production of copper and copper-base alloys in the form of sheet, strip, rod, tubing and drawn copper products. The company has also made plans for the construction of a $2,500,000 plant for the manufacture of flexible metal hose and tubing, to be located in Mattoon, Ill.

Jones & Laughlin Steel Corp. has announced a $360,000 steel 'tom-made" extruded carbon steel sections by the Ugine-Sejournet process at its new hot extrusion plant in Pittsburgh.

The **Timken Roller Bearing Co.** has announced a $360,000 steel mill expansion program to meet the increased demand for heavy walled long length tubing. The Gambrinus piercing mill will be lengthened to pierce tubing from 50 to 130% longer than lengths presently processed.

The **Strick Co.** has opened a new plant in Perkasie, Pa., for the manufacture of reinforced fiber glass. The new plant will be operated by a subsidiary, Strick Plastics Corp.

The **Dayton Rogers Manufacturing Co.** has announced a new Plastic Div. equipped especially to produce short-run plastics.

news of | SOCIETIES

The **American Welding Society** has appointed C. P. Sander, general superintendent of the Consolidated Western Steel Div., U. S. Steel Corp., a member of the Technical Council of the Board of Directors of the society.

(More News on page 202)

news of SOCIETIES

The **Drop Forging Association** at its recent Winter Industry Meeting in New York welcomed Edgard L. Harden as newly appointed vice president, secretary-treasurer. Mr. Harden will carry on the activities of this association formerly directed by retiring Raymond M. Seabury.

The **American Institute of Mining and Metallurgical Engineers** and the **American Society for Metals** are making plans for their conferees to spend nearly three weeks in Europe, from June 1 to June 19, to discuss scientific, metallurgical and production problems with leaders of the iron, steel and nonferrous metals industries of Great Britain, Germany, Belgium and France.

The **Cemented Carbide Producers Association** has recently been formed by the manufacturers of cemented carbides containing tungsten for the purpose of furthering the use of the products of the industry. Membership in the association is comprised of the majority of the producers of the product in the United States.

The **Pressure Sensitive Tape Council** at its second annual meeting elected Clarence I. Lee, president, Hampton Manufacturing Co., as president to succeed M. Davier of Van Cleef Bros. John M. Cook, vice president, Behr-Manning, was elected vice president of the council, and Richard G. Breeden, Jr., will continue as secretary-manager and treasurer.

The **Industrial Heating Equipment Association** has elected the following new officers: president—Horace Drever, president, Drever Co.; vice president—Elton Staples—executive vice president, Hevi Duty Co.; executive vice president—Carl L. Ipsen; treasurer—R. E. Whittaker, secretary, Swindell-Dressler Corp. Retiring president, L. H. Gillette, Westinghouse Electric Corp., was elected to the executive committee.

(Meetings & Expositions on p. 204)

For more information, Circle No. 484 ➤

Meetings and Expositions

SOCIETY OF AUTOMOTIVE ENGINEERS, aeronautic meeting, aeronautic production forum and aircraft engineering display. New York, Apr. 18-21, 1955.

AMERICAN ZINC INSTITUTE, annual meeting. Chicago. Apr. 28-29, 1955.

ELECTROCHEMICAL SOCIETY, INC., spring meeting. Cincinnati. May 2-5, 1955.

NATIONAL SCREW MACHINE PRODUCTS ASSOCIATION, annual meeting. Buffalo, N.Y. May 4-7, 1955.

SOCIETY OF THE PLASTICS INDUSTRY, INC., annual meeting. Queen of Bermuda. May 7-15, 1955.

NATIONAL ASSOCIATION OF CORROSION ENGINEERS, spring Northeast regional conference. New York. May 9-11, 1955.

METAL POWDER ASSOCIATION, annual meeting. Philadelphia. May 10-12, 1955.

SOCIETY FOR APPLIED SPECTROSCOPY, annual meeting. New York. May 12-13, 1955.

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION, INC., spring meeting. Hot Springs, Va. May 15-18, 1955.

PORCELAIN ENAMEL INSTITUTE, mid-year division conference. Chicago. May 18-20, 1955.

AMERICAN SOCIETY FOR QUALITY CONTROL, annual convention. New York. May 23-25, 1955.

AMERICAN FOUNDRYMEN'S SOCIETY, annual convention. Houston. May 23-27, 1955.

I. R. E. MATERIALS SYMPOSIUM. Philadelphia. June 2-3, 1955.

AMERICAN WELDING SOCIETY, Welding Show and Spring Meeting. Kansas City, Mo. June 7-10, 1955.

SOCIETY OF AUTOMOTIVE ENGINEERS, summer meeting. Atlantic City. June 12-17, 1955.

MALLEABLE FOUNDERS' SOCIETY, annual meeting. White Sulphur Springs, W. Va. June 16-18, 1955.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, semi-annual meeting. Boston. June 19-23, 1955.

AMERICAN ELECTROPLATERS' SOCIETY, Industrial Finishing Exposition. Cleveland. June 20-23, 1955.

AMERICAN SOCIETY FOR TESTING MATERIALS, annual meeting. Atlantic City. June 26-July 1, 1955.


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Time Studies
ELECTRONIC CHASSIS 12½" x 11½", with 118 holes and 4 notches was completed including setup in only 32.45 minutes and subsequent pieces in 6.44 minutes.
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AN AIRCRAFT part 7½" x 4½" with 15 holes and 1 notch was produced including setup in only 3.52 minutes and subsequent pieces in only 54 seconds.
Part of an ELECTRIC REFRIGERATOR, 39⅞" x 8½" with 10 holes and 4 notches was fabricated including setup in only 5.61 minutes and subsequent pieces in only 37 seconds.
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● How long would it take you to make a part similar to those shown above?
The difference between your production times and these typical astounding time studies is WALES Fabricators . . . the only machine of its kind.
Designed for rapid interchangeability of punch and die sizes for hole punching, notching and nibbling operations, Wales Fabricators permit working direct from blueprints or operation sheets . . . no templates required.
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Specialists in Punching and Notching Equipment
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News Digest

continued from page 14

betatrons of General Electric. Particle accelerators are more efficient, and their radiation is more easily controlled. Also, there is no radiation hazard from an accelerator once the power switch is turned off.

Plans are now definite to build two types of industrial research reactors. "Swimming pool" reactors designed by American Machine & Foundry Co., will be built for Battelle Memorial Institute and for a group of companies in the New York area. North American Aviation has contracted to build a boiling water type for Armour Research Foundation.

Swimming-pool reactor

The American Machine & Foundry Co.'s reactor utilizes a tank of water resembling a swimming pool to shield, moderate, seal and cool the reactor core. The core consists of aluminum cannisters of enriched uranium arranged in a cube at the bottom of the pool. The reactor is self stabilizing, since the water acts as a moderator to slow down the fast neutrons to energies that will sustain the chain reaction. In the event of a runaway chain reaction, the heat causes the water to boil out of the reactor core, reducing the number of slow neutrons and cutting off the reaction at a stable point. A reactor of this type does not produce usable power, but provides a variety of radiations for experimental purposes. Neutron and gamma ray flux densities in the core are over a million curies. This compares with maximum flux densities for the largest cobalt 60 sources of about 3500 curies.

The core of the AMF reactor and all structural metal near the critical area is of high purity aluminum. Aluminum was selected as the best compromise material considering cost, neutron cross section, and corrosion resistance. Hafnium-free zirco-

News Digest

nium, the best structural material for critical sections of reactor cores, is not available, and is extremely costly.

Boiling water reactor

The North American Aviation reactor to be built in Chicago is the boiling water type. In this, a solution of enriched uranium salts in water is contained in a one-foot sphere, which is enough volume to attain criticality. This reactor, too, is self stabilizing, since the bubbling caused by fast boiling will cut down the neutrons available for maintaining the chain reaction. The Armour boiling water reactor will be a power producer, with an estimated output of 50,000 w. The installation will provide radiation channels from the reactor core to enable the unit to be used for processing, research and isotope production projects.

Both types of reactors will cost over half a million dollars.

The interest in research reactors on the part of industry has been quickened by the AEC's five-year nuclear power plan, which has already authorized the construction of six reactors for power generation. Construction has begun on the pressurized water reactor near Pittsburgh, and contracts have been let for a sodium graphite moderated reactor designed by North American Aviation. Oak Ridge National Laboratory and Argonne National Laboratory are both responsible for two reactors in the plan.

An industrial group is now evaluating a liquid metal fuel reactor built by Babcock and Wilcox Co. for Brookhaven National Laboratory. The evaluation, or feasibility study, will examine a continuous process system utilizing a uranium-bismuth alloy fuel. The system is expected to provide heat for power, breed new fuel, and deliver waste products to storage tanks, all in continuous process.

(More News Digest on page 210)

For more information, Circle No. 345 ➤

News Digest

Develops Continuous Zone-Melt Technique

A continuous zone melting apparatus that delivers ultra pure material from one exit and ejects impurities from another has been developed by W. G. Pfann of Bell Laboratories. Mr. Pfann is responsible for the original batch method of zone refining which has been adopted as a standard technique in eliminating trace impurities from germanium and other materials.

The new continuous method is expected to widen the scope and utility of zone refining considerably. The method is a counterpart of the continuous fractionation column used in the field of distillation. It differs in that the solid to liquid phase is used rather than the liquid to gaseous states.

In the original batch zone melting, an ingot of material, such as germanium, is passed through a dielectric heater coil so that a molten zone sweeps from one end of the ingot to the other, depending on whether the solute raises or lowers the freezing point of the solvent. In the continuous process a central feed tank contains the material to be purified. Two long columns extending from the bottom of the tank are surrounded by moving heater coils, so that the material exists in both solid and liquid states in the columns of the apparatus. The heaters move the molten zones up one column and down the other. By means of special geometry for waste and product exit, voids that move with the molten zones are introduced into the column, thus permitting material to flow. The voids rise to the feed tank in the manner of bubbles. In the case of a rising heater, the solid is melted above the void and drips through it, causing the void to rise atop the molten zone until it reaches the supply tank. In the case of a descending heater, the molten zone descends until it hits a void, at which

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Here's an ideal organic solvent for removing practically every kind of foreign matter from metal parts. Whether it's waxes, oils, greases, tars or metal chips, you'll find that Nialk TRICHLORethylene does the job safely, thoroughly and economically, leaving parts clean, warm and dry, ready for immediate assembly, inspection or surface treatment.

Nialk TRICHLORethylene is quick acting . . . it cleans and dries rapidly. Its low boiling range (86.6–87.8°C, based on standard ASTM tests) permits vaporization at low steam pressure. (And that narrow boiling range reflects its high purity.)

Cuts power consumption . . . Nialk TRICHLORethylene can be heated by gas, steam or electricity. Its specific heat is less than ¼ that of water. You'll get concentrated vapor at only 188°F.

Nialk TRICHLORethylene is thorough . . . its low viscosity (0.58 centipoises at 20°C) and low surface tension (about 29 dynes per cm at 30°C) give rapid wetting of surfaces, plus thorough diffusion into pores and relatively inaccessible openings.

Cuts vapor loss . . . (its vapor density is 4.5 times that of air). It is completely re-usable after distillation, has no flash point, no fire point and is classed as nonflammable at room temperature and only moderately flammable at higher temperatures.

A request, written on your company letterhead, will bring you a free copy of our Nialk TRICHLORethylene booklet.

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NIALK Liquid Chlorine • NIALK Caustic Potash • NIALK Carbonate of Potash
NIALK Paradichlorobenzene • NIALK Caustic Soda • NIALK TRICHLORethylene
NIAGATHAL® (Tetrachloro Phthalic Anhydride)

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News Digest

point the void rises through the liquid phase, thus rising in a series of steps to the supply tank. At the bottom of each column, a volume of material equal to that in a void is ejected with each heater pass. Any number of molten zones, subject to the limitation of the length of the column, can be kept continuously moving through the device. The machine presents a paradoxical situation in that the melt advances through the columns continuously, although the columns are at all times blocked by solid plugs of material.

The equipment is not limited to the test tube quantities of laboratory practice. Pfann stated in his paper delivered to the AIME describing the process, that scaled-up versions indicate that the length of a liquid zone can be kept to "inches or less" with column areas of several square feet. Equipment could be built, therefore, that would subject the material being purified to many zone passes without requiring an impractical column length.

Aldip Coatings Lengthen Valve Life

Aluminum coated automobile engine valves last twice as long as standard valves, according to initial service life reports released by General Motors. The valves, coated with a protective layer of aluminum, are highly resistant to corrosion and oxidation at high temperatures. The Aldip method, developed by GM, has been used with success on exhaust manifolds, heat exchangers and turbine engine components. Application to automobile poppet valves is the first application of the coating to moving parts of an engine, however.

The progress report, presented to the SAE by representatives of General Motors Research Laboratory, described two methods of applying the coating. The original method, which has been li-

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censed to other concerns, is to preheat the steel in a special patented salt flux and then dip it into a bath of molten aluminum. Excess aluminum is blown, spun or shaken off when the part is removed from the coating dip.

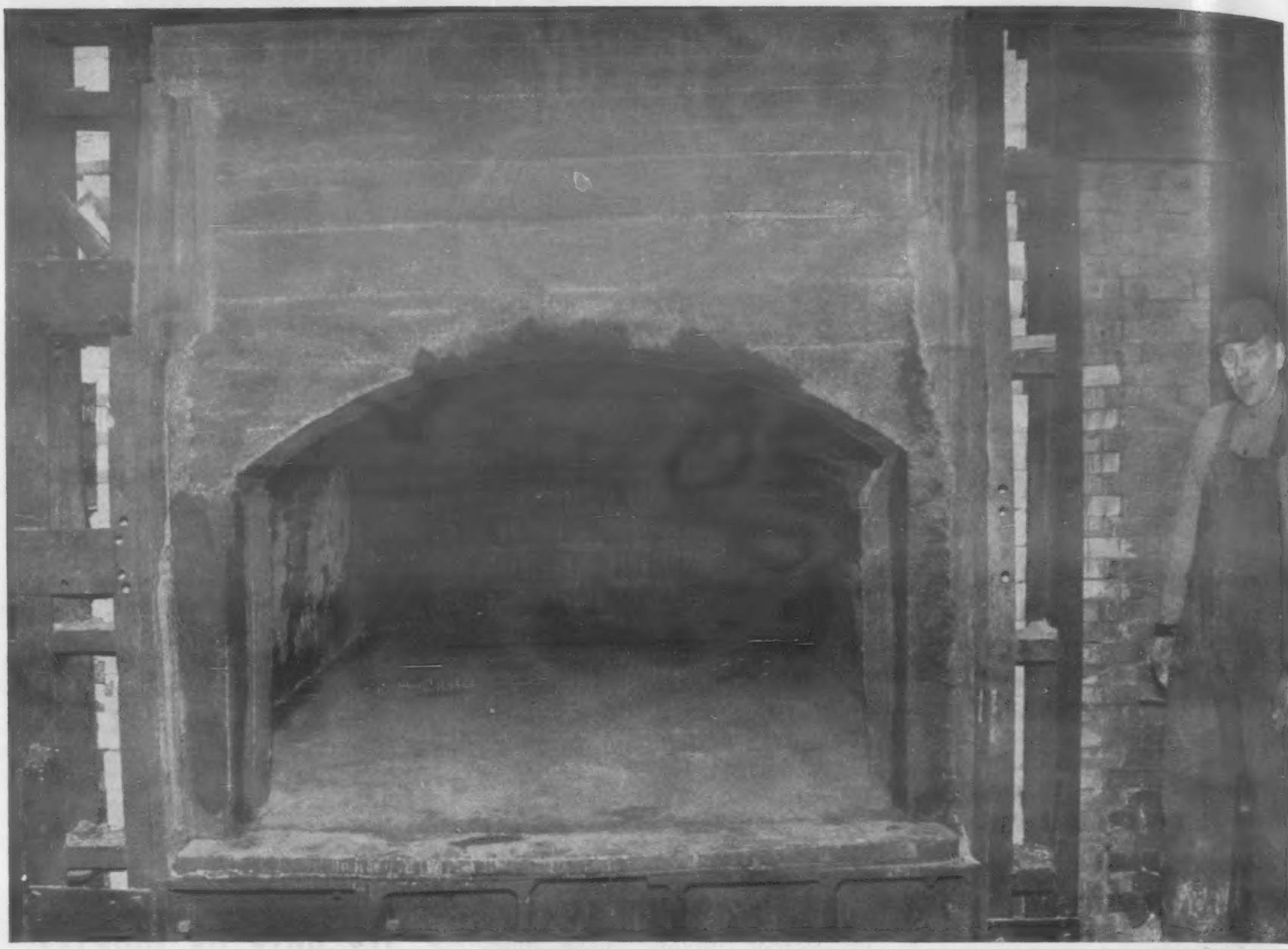
A newer method has eliminated the dipping operation. Aluminum is sprayed on the part; then the part is heated in a flux bath until the aluminum melts and spreads over the surface of the steel. The spray technique allows even application of aluminum and permits greater control over the area to be coated and the thickness of the coating.

Road and dynamometer evaluation tests of coated valves indicate that valve life can be increased up to twice the accepted standard. In one series of truck tests, four plain valves failed without a coated valve failure. In tests on 18 cars, no coated intake valves and only three coated exhaust valves failed. Among the uncoated valves in the test series, 27 exhaust and 13 intake valve failures occurred. In dynamometer tests conducted on engines with alternate coated and uncoated valves, the poorest Aldip valve outperformed the best uncoated valve.

General Motors is using the coating technique in the Production Divisions of Chevrolet and Pontiac. Thompson Products and Rich Manufacturing have been licensed to develop the process for other applications. The success with poppet valves points the way to possible applications in turbine engine parts and other moving parts that are threatened by corrosion and oxidation at high temperature.

Liquid Helium Used In Tests

Using a metals stress and strain testing chamber in which liquid helium is used to attain temperatures as low as —452 F,



EASY-TO-CAST REFRACTORY CONCRETE forms front wall of in-and-out billet and slab heater at Industrial Forge & Steel, Inc., Canton, Ohio. Refractory Concrete gives trouble-free service despite furnace-crown temperatures of 2200-2250°F.

Here's how Refractory Concrete cuts installation time . . . improves performance

THIS BILLET HEATER front wall is only one example of the ways that Refractory Concrete serves Industrial Forge & Steel, Inc., Canton, O. Refractory Concrete is used on hearths for in-and-out furnaces . . . on charging floor areas for open-hearth furnaces . . . to line billet furnace doors and pre-heating pits. Placed in 5 hours, a refractory concrete bridge wall for a coal-fired boiler gave better service than previous walls that took 2 days to install!

You'll find that Refractory Concrete made with Lumnite* calcium-aluminate cement gives trouble-free service wherever heat, corrosion or abrasion are problems. It's easy to place—by plastering, pouring or cement gun—and it's ready for use within 24 hours.

For added convenience you can use a Lumnite-base castable mix—Lumnite cement plus aggregates selected for specific temperature and insulation needs. All *you* do is add water, mix and place. Castables are made and distributed by leading manufacturers of refractories. For more information, write Lumnite Bureau, Universal Atlas Cement Company (United States Steel Corporation Subsidiary), 100 Park Avenue, New York 17, New York.

INTERIOR VIEW of heater. Refractory Concrete made with Lumnite reaches service strength within 24 hours . . . takes temperatures up to 2600°F. and more.

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researchers at Westinghouse Electric are learning more about the behavior of metals at low temperatures.

Results of tests will tell engineers which metals are best suited for use under extreme temperature ranges. Information of this sort will be useful in the design and development of guided missiles and aircraft.

For fuel cells

"It is not at all impossible," E. T. Wessel, research engineer for Westinghouse, explained, "that aircraft of the future will use fuels which are stored as liquefied gases in metal containers at extremely low temperatures. Preliminary studies of the properties of metals at low temperatures will be essential to developments of this kind.

"Oxygen for human consumption during high altitude aircraft operation already is being stored in liquid form in metal containers at temperatures of about −300 F. This arrangement is more practical than using compressed gas since an equivalent size storage space can contain a much larger supply of oxygen in liquid form."

Although much larger testing apparatus has been used at low temperatures in the past, the Westinghouse-developed chamber, which is only slightly larger than a hand fire extinguisher, is believed to be the first of its kind in the world to use liquid helium in order to attain the −452 F mark for purposes of

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tension testing. Liquid helium is produced in cryostats developed by A. D. Little, Inc.

The extremely low temperatures allowed are just short of the absolute zero reading of −459.6 F, the point at which, theoretically, all molecular motion ceases.

Prior to the use of liquid helium as a refrigerant, tests were conducted at temperatures as low as −320 F by using liquid nitrogen.

Lower temperatures

Temperatures unheard of even in the most severe climates now are frequently encountered in national defense, industry, and laboratory research work. New engineering problems have arisen from this work and have led to intensified research programs. The aims of such investigations are concerned with obtaining a better understanding of the strength of metals and the factors which cause brittle failures. For example, he pointed out that normally used steels become brittle, and rubber loses its elasticity when subjected to the low temperatures obtainable with liquefied gases.

The Westinghouse-developed cold test chamber works like this:

A sample of the metal to be tested, about 1 in. long, and ¼ in. in diameter, is placed inside the special vacuum insulated chamber. Gripping it at either end are two special Discaloy rods. Discaloy is an alloy developed several years ago by Westinghouse to withstand high temperatures and high stresses for extended periods of time. It has been recently discovered that Discaloy is also a very good material for low temperature applications. Liquid nitrogen is forced into the chamber first to cool it from room temperature to −320 F. At this point the liquid helium takes over and the temperature may then be dropped to −452 F.

Nitrogen is used in the room

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temperature to −320 F range, the Westinghouse engineer explained, because it is considerably more economical and efficient than is the use of helium at these temperatures. By the use of these two refrigerants, tests can be conducted at any temperature from 0 to −452 F.

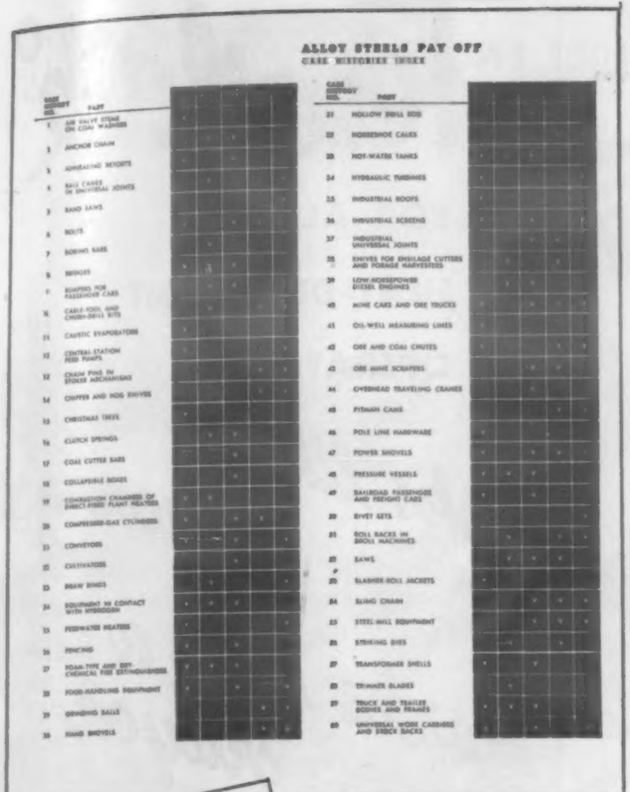
Metal sample pulled apart

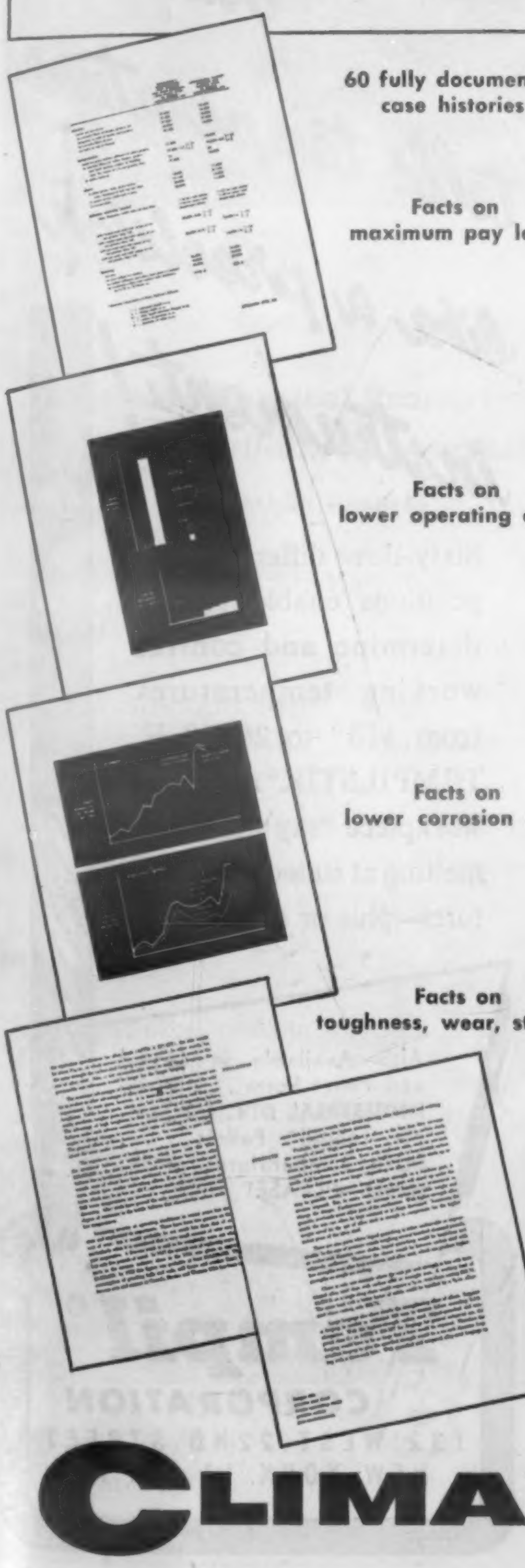
When the inside of the chamber and the test sample have cooled to the desired temperature, the test is started by applying a load to the Discaloy grips in such a fashion as to pull the sample apart. The load is applied until the piece of metal being tested breaks. During the test the temperature of the test piece and also the stress-strain readings from the sample are recorded electrically on graphic charts. In current experiments the maximum stress which can be applied to the ¼-in. dia sample is 260,000 psi.

In addition to the possibility of the tests providing basic engineering data necessary to the development of such things as low temperature liquid fuel and coolant storage tanks for guided missiles, Mr. Wessel said the studies are expected to provide information which will improve our understanding of why metals behave as they do under various conditions, with particular reference to brittle failures such as have occurred in the welded steel hulls of ships at sea. The fact that low temperature liquids are being considered for coolants in guided missiles was disclosed in Sept., 1954, in Boulder, Colo., at the dedication of the new National Bureau of Standards laboratories there.

Big Presses Form Plastics

Expanded facilities for forming reinforced plastics are operating at Goodyear Aircraft Corp. following installation of five





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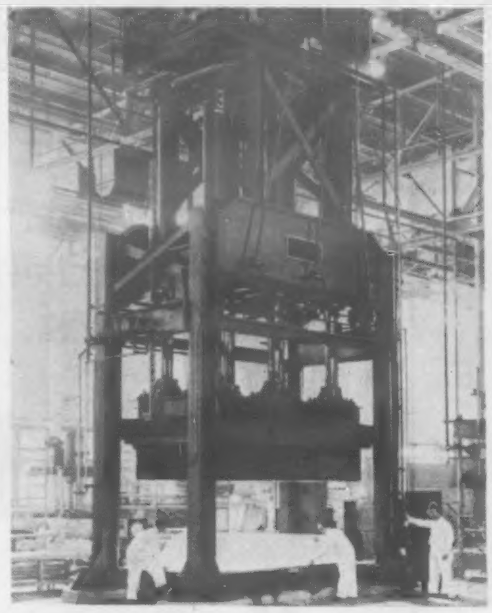

***A 700-ton press** for molding reinforced plastics is largest designed specifically for this use. Here it is set up to mold boat hulls.*

heavy presses. The presses, which range in size from 100 to 700 tons, plus auxiliary equipment, cover an area of 25,000 sq ft assigned by the company to the production of canopies and laminates.

The over-all facility, perhaps largest of its kind for the production of reinforced plastic items, will accommodate mass production schedules. The heavy press line-up will turn out sizable plastics parts, such as automobile bodies, boats, fuel tanks, packaging cases, missile and other complex aircraft components, farm implements and a variety of other products.

The equipment, which required a year to install, includes in addition to the 100 and 700-ton presses, three 100-ton units. All are hydraulically operated. Supplemental equipment includes preforming machines, ovens, mixers and grinding booth.

First job for the imposing 700-ton press, largest of its kind, is the production of one-piece hulls for outboard boats, to be marketed by Bowman, Inc., boat manufacturers of Little Rock, Ark. Goodyear Aircraft has been producing optically-clear canopies, in addition to a variety of reinforced plastic products since 1945.

(More News Digest on page 224)

For more information, turn to Reader Service Card, Circle No. 315

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Castings Society Announces Awards

The Steel Founder's Society of America have announced the winners of the 1954 Product Development Contest. Winning entries of the two classifications, members and non members of the SFSA, are pictured in Materials at Work on page 116.

The winners of Class I, members of the SFSA were: first place—Sands Falk and David Miller, for a steel cast double acting cylinder for gas transmission pumps; second—Robert J. Frank of Superior Steel and Malleable Castings Co. for a redesign of spring equalizer and hanger brackets as a casting rather than a weldment. Third place was a tie between Vernon Lick of Granite Steel Castings Corp. and Roy W. Daub of Lebanon Steel Forging. Lick's entry was a cast-weld shakeout unit, and Daub's was a cast louvre grill for the M48 tank.

Winner of Class II (non members of the SFSA) was Roy Groethe of Corning Glass Works, for contour chill castings for glass molds. Second place went to Charles Babb of Allis Chalmers Mfg. Co. for cast steel weldments for a centrifugal pump barrel. Third place was awarded to R. P. Fox of Clyde Iron Works for cast steel crane hooks, redesigned from hand forgings.

Electroplaters' Technical Program

Titles of papers scheduled for presentation at the 42nd annual convention of the American Electroplaters' Society have been announced by the convention committee.

Completion of the technical program, to be held in Cleveland, June 20th through 23rd, 1955, is announced by Eugene L. Combs, general chairman. Mr. Combs reports that the subjects are calculated to cover the most significant operating areas for pro-

Harnessing heat for safety's sake

3M ADHESIVES

A temperature of 215° F. is just too hot to handle, no matter where you find it. Yet today's wall-type room heater must operate at just such a temperature *inside*, while staying cool enough on the *outside* so that even a child can touch it in perfect safety. What's behind this bit of modern insulation magic? A 3M product called EC-226—the versatile adhesive you see in action above.

Applied quickly and easily by spray, EC-226 has "quick strength" . . . takes a gentle grip on the insulation immediately upon contact, simplifying the manufacturer's assembly operation. Then the adhesive dries to form a lasting bond that *keeps* the insulation at its cooling job—without a slip—despite the boiling-hot temperatures generated inside the heater.

See what adhesives can do for you . . .

Call upon 3M research for the solution to your specific design or production problem. Call an expert, your nearest 3M Field Engineer—or write for further information to 3M, Dept. 14, 417 Piquette, Detroit 2, Mich.

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ducing better finished products at lower cost to industry.

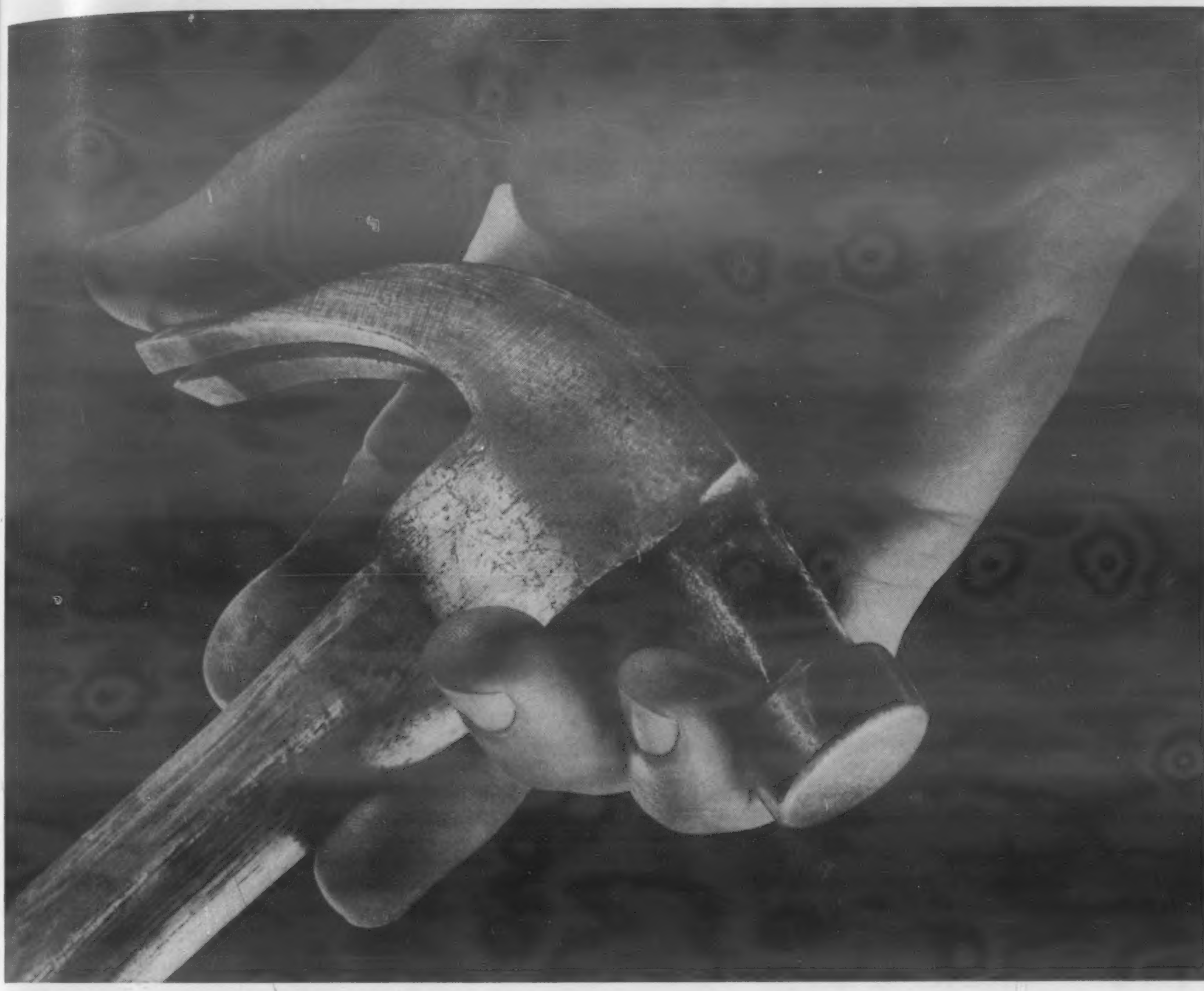
Tentative titles of the papers are:

- Liquid Level Control
- Recovery of Waste Cyanide Zinc
- Plating Powdered Metallurgy Bronze Parts
- High Speed Brass Plating
- Materials of Construction for Plating Rooms
- Anodic Etch of Ferrous Parts Before Plating
- Surface Preparation
- Fatigue of Plated Steel Parts
- Job Shop Costs
- Tin Plating of Copper Wire
- Nickel and Copper Plating on Coils
- Copper Plating on Steel for Telephone Drop Wires
- Effect of Ripple on Plating
- Filtering and Handling of Chromic Acid Solutions
- Handling of Waste and Waste Treatment
- Finishing and Plating of Beryllium and Beryllium Alloy
- Vacuum Metallizing
- Anode Current on Phosphatized Copper Anodes
- Flow Coating of Paint

The Industrial Finishing Exposition, to be held concurrently with the technical sessions in Cleveland's Public Hall, will attract about 200 exhibitors of finishing equipment, services and supplies, according to Mr. Combs. Exhibits will occupy both the upper level hall and the lower level hall. Two meeting rooms, one on the upper level and another at the lower level, will house the technical sessions.

Last show sponsored by American Electroplaters' Society was held in Chicago in 1952.

Attend the
1955 Metal Powder Show and 11th Annual Meeting
Philadelphia, May 10-12
See page 17 for details.



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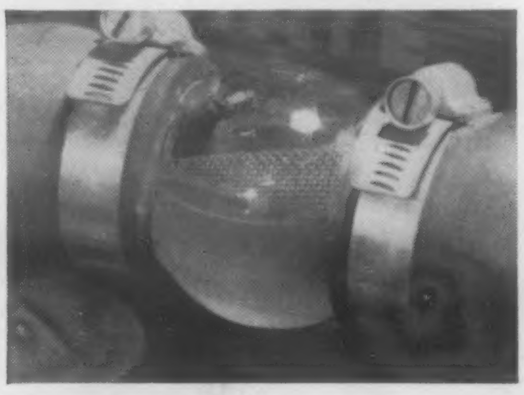
CORNING GLASS BULLETIN

FOR PRODUCT DESIGNERS

Purposeful package for those who don't trust rust . . .

Not exactly helpful to the motor that drives your mechanized buggy is rust in the radiator.

That's why the "Rust-Kleen Cone" came into being, a product of Pinard & Co., Manchester, New Hampshire.



As you can see from the picture, this handy-dandy item consists of a metal cone filter, neatly ensconced in a glass bulb. This diminutive defender fits between the radiator and the block, spliced, as it were, between a couple of lengths of hose.

The basic purpose is to keep rust from clogging the radiator. Method—the cone sets up a swirling motion which breaks up the rust into fine particles.

Bulb made of a PYREX brand glass is a multi-purpose package. First off, since it's immune to thermal shock, it can cope with hot water in circulation, without breaking, even when ambient temperatures hover near zero.

Glass also permits visual inspection for checking water pump and thermostat operation. Moreover, you can see whether you have enough water without taking off the radiator cap.

And, if the motor happens to be so unfortunate as to acquire a cracked block or leaking head gasket, tell-tale gurgles appear in the glass bulb.

Thus, the glass bulb's unique combination of "see-through-ness" plus resistance to temperature changes plus ruggedness make for maximum utility.

A small item, this, but typical of the new products people develop. It's also typical of the design for inexpensive mass production you can expect when you work with Corning engineers.

Even Edison's filament was just a bright idea till he came to Corning to talk about a cover for it. Thus, glass enclosures for ingenious brain-children are a tradition with us.

Perhaps your next inspiration can get a boost . . . through glass—either in the making of it, or in the product itself. We can start at your convenience.

PYREX pistol for hot stuff— Sampling molten metal may not sound like a task you'd ordinarily assign glass to. But, the Leco people from out St. Joseph (Mich.) way do.

Their pistol-like contrivance for "shooting" samples of molten metals is fitted out with a barrel made of PYREX tubing. Cock the gun, dip the barrel momentarily into the molten mix, and a sample of the hot stuff is sucked right up into the tube where it solidifies. After that, you break away the "crazed" tubing and subject the metal to whatever tests you wish.

As the Leco engineers have discovered, PYREX tubing is both inexpensive and readily available. A long piece for the barrel of this sampling gun protects the person taking the sample and keeps the sample surface shiny and free of oxidation—a real timesaver compared with older methods of preparing samples for testing.

Actually, we don't ordinarily call attention to the *breakage* applications of PYREX tubing, or for that matter, of any of the other glass products we make.

Forsooth—our usual message speaks, with due modesty, of physical strength, resistance to thermal shock, and over-all ruggedness. And that perhaps points up one of the real virtues and attractions of glass: its ready versatility and adaptability to uses and purposes not even glimmered at first.

Take for another example (from our files of happy customers) the use of expendable glass in plastic molding. Manufacturers of such diverse items as billiard balls, insulators, and catheters have found glass an ideal (well, almost) material for molds. For one thing, glass being nonadhesive, the plastic doesn't stick to the mold. Glass molds cut processing costs, too, since like the metal samples in the Leco gun, plastic products molded in glass come out with a smooth finish.

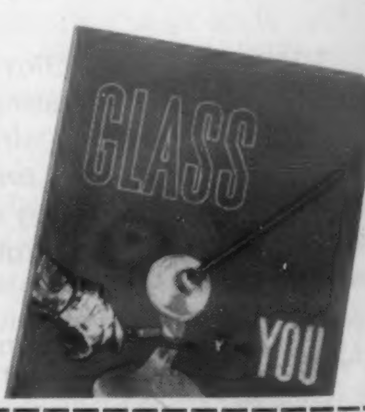
Which, in a round about way, brings us to say that . . .

You are cordially invited . . . to find out if one of the 50,000-odd glass formulas on tap at Corning holds the answer to one of your pesky materials problems.

At the risk of repeating ourselves we point with pride to the diversity of aptitudes that we can custom-build into glass at your behest. Be it product or process that's on your mind, there's probably already a glass (maybe even a finished product ready to mass produce) that can meet the chemical, physical, mechanical, electrical, and optical qualities you're looking for—not to mention the compelling beauty of things made of glass.

Good starting point for getting acquainted is our copiously illustrated little primer called "Glass and You." It's a painless introduction to this wonderful world of glass, telling and showing how and why this centuries-old material is the able ally of our mid-20th century technology.

Along more specific lines, we'll be happy to fill (for free) your order for such handy reference items as you'll find listed in the coupon below. Your check mark in the appropriate box does it.



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